RADIUM

ITS PHYSICS & THERAPEUTICS

DAWSON TURNER

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PLATE I.

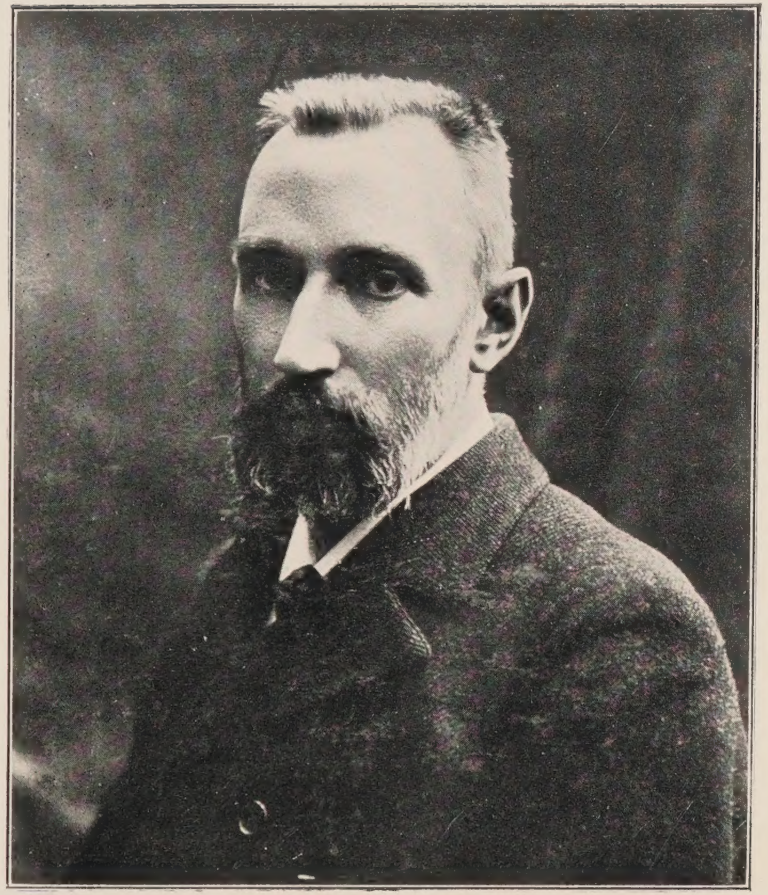

FIG. 1.—MONSIEUR CURIE.

FIG. 2.—MADAME CURIE.

Frontispiece.

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LONDON
BAILLIÈRE, TINDALL AND COX
8, HENRIETTA STREET, COVENT GARDEN
1911

PREFACE

While several works dealing with the physical phenomena of radio-activity have recently been published, and numerous articles have appeared in the medical journals upon the therapeutic uses of radium, there yet seems to be the want of a small manual suitable for medical men, which should embrace both of these topics. In this volume an attempt has been made to supply this want in a concise form.

The writings of Professor Rutherford and Professor Soddy, as well as those of Dr. Wickham, Dr. Degrais, and Dr. Dominici, have, owing to their high authority, been largely made use of throughout this work. In addition the author records his own observations founded upon a five years' experience of the use of radium as a therapeutic agent.

The author's grateful thanks are due to his colleagues in the Edinburgh Royal Infirmary, and other medical friends, for kindly permitting him to quote some of the cases treated by him for them.

DAWSON TURNER.

37, George Square,
Edinburgh,
November, 1910.

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RADIUM:

ITS PHYSICS AND THERAPEUTICS

CHAPTER I

DISCOVERY OF RADIO-ACTIVITY—LIST OF RADIO-ACTIVE SUBSTANCES—CHARACTERISTIC EFFECTS—ALPHA RAYS

The discovery of radio-activity was made by M. Henri Becquerel in Paris in the year 1896, about a year after the memorable discovery of the X rays by Professor Röntgen in Germany. The extraordinary properties of the X rays, and their evident connection with the fluorescence of the glass of the X-ray tube, led experimenters to examine other phosphorescent or fluorescent bodies for the same type of radiation. M. Henri Becquerel in particular studied the phosphorescent substance uranium. A phosphorescent body is one which continues to glow in the dark after it has been exposed to a strong light; the luminous paint with which match-boxes are sometimes covered is an example. M. Becquerel placed a sensitive photographic plate in a light-tight envelope, covered

it with a uranium salt, and placed it outside in the sunlight; he found that the plate was affected just as though it had been exposed to the X rays, for one of the extraordinary properties of the X rays is their power of penetrating opaque bodies and of affecting photographic plates. He thus discovered that uranium when exposed to sunlight gave off a radiation akin to the X radiation. But he went farther, for one day it happened to be raining, and he placed his photographic plate with the uranium upon it inside a cupboard; on developing this plate he found it as much affected or fogged as the others which had been in the sunlight. He was not slow to see the importance of this, and he repeated the experiment, taking care that the uranium was kept in the dark all the time. The result was the same: the plate was as much affected in the dark as in the light, and neither phosphorescence nor sunlight had anything to do with it. He thus arrived at the epoch-making discovery of radio-activity. The property is an inherent one of the element uranium; it is found in all its compounds, and the radio-activity of such a compound is proportional to the amount of uranium which it contains. Thus it is an atomic property, and no chemical or physical processes to which the uranium has been subjected have so far been able in the smallest degree to affect its radio-activity. It remains the same at the heat of the electric furnace and at the cold of liquid air. Other substances were soon tested for the same property; Schmidt found that thorium and its com-

PLATE II.

FIG. 3.—GAS-MANTLE CONTAINING THORIUM, PHOTOGRAPHED BY ITS OWN RAYS.

To face page 2.

pounds, and Debierne that actinium, were radio-active. But the most important discoveries were made by M. and Mme. Curie and M. Bémont. Mme. Curie, then a student in Professor Curie's laboratory, took up the subject of radio-activity as a thesis for her degree, and made quantitative measurements of the radio-activity of a large number of minerals. She found, with the assistance of Professor Curie and M. Bémont, that pitchblende and oxide of uranium were even more radio-active than uranium itself. It was evident that the ore must contain a body more highly radio-active than uranium, and this body she set herself to isolate. The only test she had for it was its radio-active power, and the method she adopted was to endeavour by various chemical processes to separate from the ore the radio-active element. The process was a most laborious one, but ultimately a substance was obtained, though in very small quantities, which was two million times more active than uranium. At first only a tenth of a grain was obtained from 2 tons of the uranium ore, but the German chemist Giesel afterwards succeeded in extracting 4 grains from 1 ton of the best pitchblende, which is found in the celebrated Joachimsthal mine in Austria (Fig. 4). The Austrian Government very generously aided the Curies by placing several tons of pitchblende at their disposal. The new element extracted by the Curies was named Radium. It belongs to the group of the alkaline earths, and is closely allied to barium ; its atomic weight was found

to be 226, and its spectrum characteristic of the alkaline earths. The pure metal has recently been isolated by Mme. Curie and M. Debierne, but we know it chiefly in the form of its compounds. These are the bromide, chloride, nitrate, sulphate, and carbonate; the first three are soluble, the last two are insoluble. When, therefore, we speak of pure radium, we mean the pure salt, and of these the bromide is the commonest.

Radio-active Substances.—The radio-active substances separated, of reasonably slow period of transformation, are—uranium, thorium, radium, actinium, ionium, and radiolead (radium D).

Of other radio-active substances of shorter life there are—polonium, radiothorium, mesothorium; in addition to these there are a large number of other substances like the radium emanation, radium A, B, C, thorium X, and many others, which have a period of transformation measured in days or weeks. These bodies are distinguished from such substances as radium by the difference in their period of transformation and in their chemical and physical properties.

The period of an emanation means the time required for its activity to fall to half value.

All of these substances are of high atomic weight, and the value 226 places radium in the position of the third known heaviest element; uranium leading the way with an atomic weight of 238, and thorium coming next with an atomic weight of 232.

Probably there are other bodies which are radio-

PLATE III.

FIG. 4.—PITCHBLENDE.

To face page 4.

active ;* in fact, every form of matter may be found in the future to possess this property in some degree, an atomic property as unalterable as mass. The dates which are important in this new line of research are as follows :

Sir W. Crookes discovered the cathode rays in 1879.
Professor Röntgen discovered the X rays in 1895.
M. H. Becquerel discovered radio-activity in 1896.
The Curies discovered radium in 1898.
Professor E. Rutherford made known his theory of atomic breakdown in 1903.

Characteristic Effects.

The four characteristic effects of radio-active bodies are—

1. They affect sensitive photographic plates in much the same manner as light.

2. They produce fluorescence — *i.e.*, they cause certain substances, such as barium platinocyanide and diamonds, to glow with a visible light.

3. They ionize the air—*i.e.*, they cause it to become a conductor of electricity, so that a body charged with electricity becomes discharged.

4. They produce heat.

Some of their other effects are the emission of light, the decomposition of water and various gases, the oxidation of metals in air—for this reason it is said that radium should not be preserved in an aluminium case, lest the case be eaten away by the

* The salts of potassium and rubidium give off beta rays.

oxidation (the writer has not observed this effect)—iodine is liberated from iodoform, glass and vitreous bodies are coloured violet, certain physiological and pathological effects are produced: these will be referred to later.

Chiefly from Professor Rutherford's work we know that these effects are due to the rays and emanation which radio-active bodies give off. The rays are divided into three kinds, known respectively as alpha, beta, and gamma rays, and each of these demands careful consideration.

The **alpha rays** are not really rays at all, but are projectiles fired out by the radium as though it were a perpetual Maxim gun. A grain of radium bromide expels each second about ten thousand million alpha particles. They carry a positive charge, their mass is four times that of a hydrogen atom, their velocity is about one-tenth that of light, and there are conclusive reasons for believing either that they consist of helium or that they become converted into helium, that strange inert element so long known to exist in the sun, but only recently discovered on earth. The atomic weight of the alpha particle is the same as that of helium, and Sir W. Ramsay and Mr. Soddy have found that the spectrum of helium gradually appears in a tube into which only the emanation of radium has been put. Thus is the dream of the alchemists fulfilled—there is a transmutation of one element into another: the element radium has changed into the element helium, the nobler into the baser

metal, and we have the antithesis of a substance of absolutely negative properties and of very small atomic weight being produced by a substance of altogether extraordinary properties and of exceedingly high atomic weight. But this is what we might expect; the radium atom disintegrates, explodes, there is a stupendous liberation of energy, and naught but inert shattered débris remains. There are really four kinds of alpha rays, distinguished from one another by their range of penetration; but they are relatively very easily stopped, a single sheet of note-paper will intercept them, and the most penetrating type can only get through 3 inches of air and then are stopped, or, rather, cease to be detectable. It is obvious that, even if the radium be applied directly to the skin without any screen or protective covering, the alpha rays will be stopped by the outermost layer of the tissues, and therefore can only be used for the most superficial conditions. A consequence of this is that it is rarely possible to make any therapeutic use whatever of these rays, and that is to be regretted, as the greater part of the energy of the radium resides in them.

CHAPTER II

BETA RAYS—ELECTRONS—GAMMA RAYS—PENETRATIVE POWER—MAGNETIC DEFLECTION—EMANATION

The **beta rays** will be best understood if a reference be first made to Crookes' experiments in 1873 and 1879. Long ago Sir W. Crookes had studied the phenomena of vacuum tubes; he succeeded in 1873 in emptying a glass tube of its air more thoroughly than had ever been done before. He brought the pressure of the residual air in the vacuum tube down to about the one-millionth of an atmosphere, and then forced a current of electricity through it. He now made the striking discovery that the electric current was transported through the tube by a shower of extremely minute particles, which, starting from the negative pole or cathode, travelled in straight lines, and caused a beautiful phosphorescent glow on the glass walls facing them. This was a true convection current of electricity, and it was travelling in the opposite direction to the currently accepted direction. Crookes called these flying electrified particles "the cathode stream," or "radiant matter," or "a fourth

state of matter." Radiant matter was prophetic, but he was ridiculed for these words.

Since Crookes' discovery our knowledge has advanced; we now call these tiny particles **electrons.** The electron is a unit of negative electricity, a disembodied charge without material substance, and its apparent mass is only the one-thousandth of the mass of a hydrogen atom.

Experiments by Sir J. J. Thomson and others have shown that the beta ray of radium is, to all intents and purposes, the cathode stream of the Crookes tube. It is therefore no more a ray than the alpha ray; it consists in a stream of electrons, identical in charge and mass with those found in a Crookes tube, but travelling more rapidly. The enormous electric force at the back of the electron in the Crookes tube is quite incompetent to give it the velocity with which it is ejected from radium. The velocity of the beta particle or electron is nearly equal to that of light; it is as high as 170,000 miles a second. Owing to their great speed and small size, they have much greater powers of penetration than the alpha particle. According to Rutherford, the relative penetrating power of the three types of rays is about in the ratio 1 : 100 : 1,000. While a piece of mica or paper is sufficient to stop the alpha ray, it would take 1 centimetre of lead to insure that all the beta rays were intercepted. The beta rays, like the alpha, can be subdivided into different groups according to their range of penetration. Thus we can speak of hard

and soft rays, just as we do of the Röntgen rays. They are readily deflected by a magnet. Four thousand of them would be required to balance a single alpha particle.

The **gamma ray** differs from the preceding rays chiefly in its great powers of penetration, and in its non-deflectibility by the most powerful magnetic field.

In amount as compared with the alpha and beta rays they are few; but though relatively feeble, their extraordinary powers of penetrating dense matter make them of great interest. If a fluorescent screen be placed half a metre away from a centigramme of radium in a dark room, it will be observed, by an eye which has been long enough in the dark to become sensitive, to be slightly luminous; if now a five-shilling piece be placed against the radium so as to intercept the radiation, the luminosity will be a little diminished, because those beta rays which had succeeded in reaching the screen will be cut off. All the luminosity will now be due to the gamma rays, and it will be found that the luminosity will not be diminished even if a human body be interposed between the radium and the screen.

This is not the case with the X rays; the most penetrating X rays would be robbed of much of their intensity by such a screen. For this reason radium rays are unsuitable for taking radiographs of the body; the beta rays are not penetrating enough, and the gamma are too penetrating to throw shadows. The nature of the gamma ray is disputed; at first con-

sidered, owing to their magnetic non-deflectibility, to be a pulse or wave motion in the ether, there are now philosophers who regard them as discrete particles, but electrically neutral (positive and negative united). The question, then, is not settled. At any rate, the gamma rays are always found in company with the beta, much as the cathode ray and X ray go together. If the gamma ray is proved to be a particle instead of a wave motion, we may have to revise our views as to the nature of the X ray.

There are two chief methods of separating the alpha, beta, and gamma rays from each other:

1. By their penetrative power.
2. By their magnetic deflection.

A sheet of note-paper or 3 inches of air will cut off the alpha rays, leaving only the beta and gamma; 1 centimetre of lead will cut off the beta, leaving only the gamma.

If the rays from a radium salt are caused to traverse the space between the poles of a powerful electro-magnet, the alpha rays will be slightly bent in one direction, the beta strongly in an opposite, and the gamma not at all (Fig. 5).

If the magnet be a very powerful one, the beta rays may be bent up into spirals; the alpha rays suffer only the one-thousandth part of the deflection that the beta undergo. This magnetic analysis or separation is not at present to be recommended as a means of separating the rays for purposes of treatment.

The **emanation** of radium is being constantly pro-

duced, but it is only freely liberated when radium salts are dissolved in water or heated. The previously formed but imprisoned emanation can now escape. The radio-activity of radium, thus freed from its emanation, is very much reduced, but as it continues to form fresh emanation it again gathers strength until its activity is completely restored.

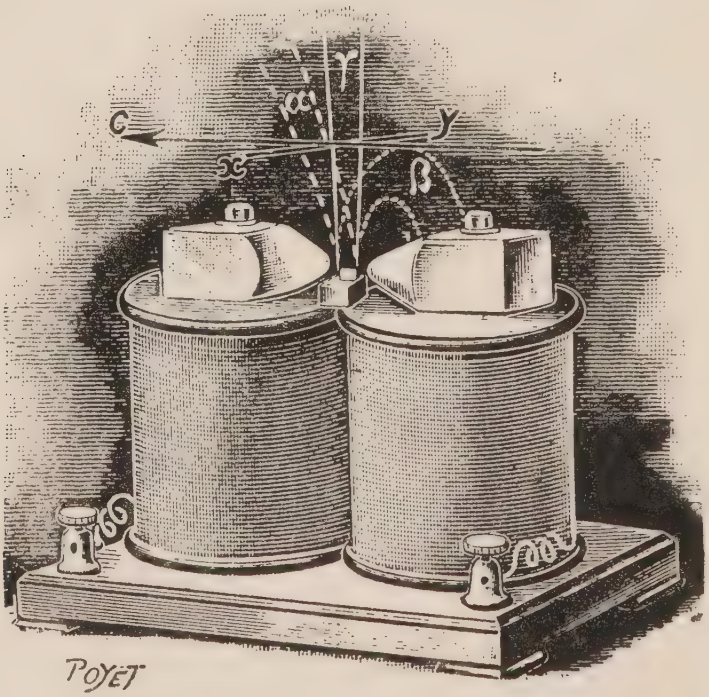


Fig. 5.—Magnetic Deflection.

The emanation is intensively radio-active, mass for mass far more so than radium itself; it gives off alpha rays at first, and then beta and gamma. Its radio-activity does not last long; in four days it is reduced to one-half, and in about a month it has disappeared altogether. While it is losing, the radium is regain-

ing radio-activity, and shared between the two there is a radio-active equilibrium (Fig. 6).

The emanation is a true gas which can be condensed into a liquid at − 150° C.; it does not appear to have any power of entering into chemical combination or of being absorbed by any reagent; it belongs to the argon group, and is a new radio-active element. The gas is

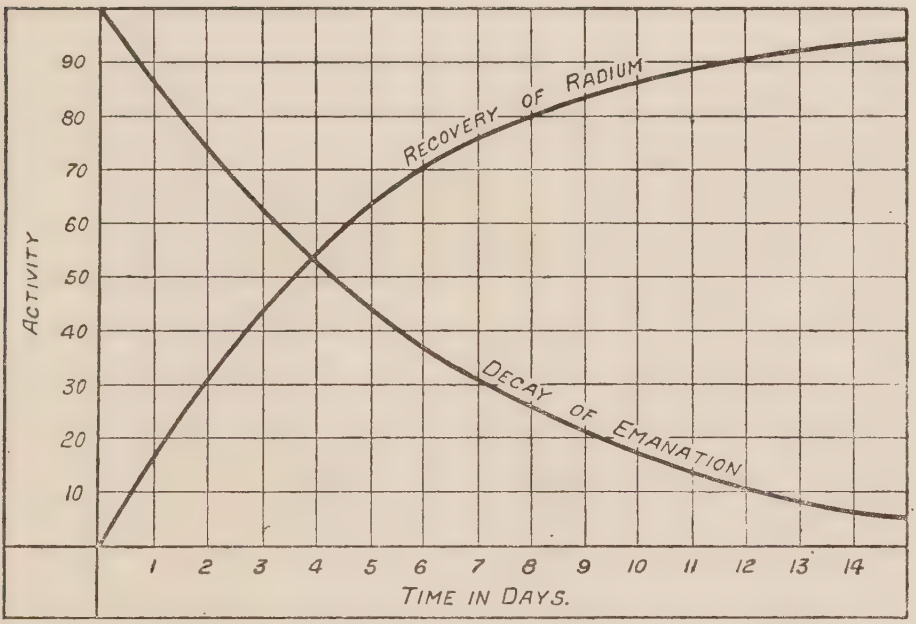
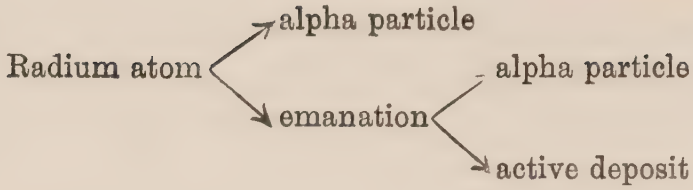


FIG. 6.—CURVE OF DECAY OF EMANATION AND OF RECOVERY OF RADIUM.

very dense, its atomic weight is 222; it is regarded as being what is left of the radium atom after an alpha particle has been discharged (Fig. 7).

The alpha particle (helium) has an atomic weight of 4; and if this number be taken from the atomic weight of radium (226), there is left the number 222, which is the atomic weight of the emanation.

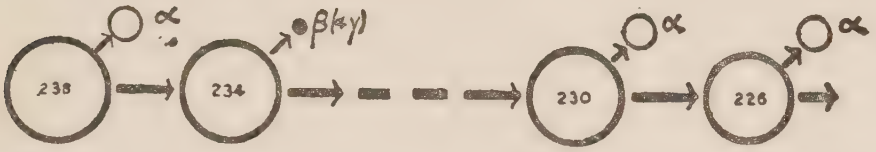


To obtain the emanation in a pure state, advantage can be taken of its property of condensing at $-150°$ C. A small crystal of a salt of radium is put into a small Woulff's bottle, and a few cubic centimetres of water added to dissolve the salt. If a current of air be now sent through the solution, the released emanation will be carried along with it, and if passed into a U-tube cooled by liquid air will condense in the tube in a pure state. Its presence may be well shown by introducing a little fluorescent zinc sulphide or willemite into the tube; for this will glow brilliantly when the emanation reaches it, and this luminosity will be enhanced when the emanation condenses.

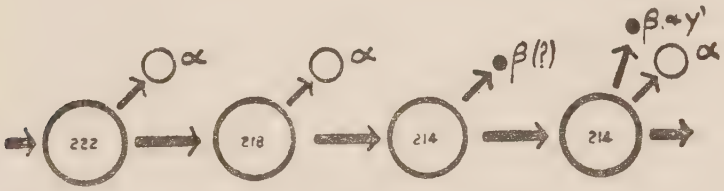
A simple method of preparing the emanation for therapeutic purposes will be described later on.

Any body exposed to the emanation becomes temporarily radio-active. This induced radio-activity is produced by the active deposit of the emanation. The emanation gives off an alpha particle and changes back into a solid, the active deposit. The solid is called radium A; this in turn gives off alpha and beta particles, and changes into radium B. Radium B changes into radium C; the latter gives off alpha, beta, and gamma rays, and changes into radium D. And so on through similar disintegrations until a

body called radium G is reached. This body is believed to be lead; and that is as far as the disintegration series of uranium is at present known.



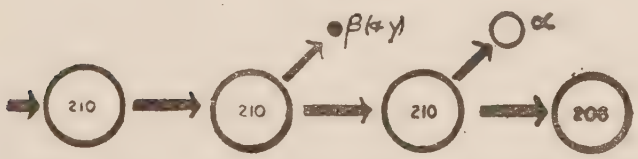
Uranium. 7,500,000,000 years. | Uranium X. 35·5 days. | Parent of radium. Ionium. | Radium. 2,500 years.



Emanation. | Radium A. | Radium B. | Radium C.

Active deposit of rapid change.

5·3 days. | 4·3 minutes. | 38 minutes. | 30·5 minutes.



Radium D. | Radium E. | Radium F. (Polonium.) | Radium G. (Lead ?)

Active deposit of slow change.

24 years. | 7·25 days. | 203 days.

FIG. 7.—DISINTEGRATION SERIES (PROFESSOR SODDY).

Radium F is the polonium discovered by Mme. Curie before the discovery of radium. Some of these changes take only a few minutes, and some take many years. One more word about the active deposit of the

emanation : it tends in an electric field to concentrate itself on the negative electrode ; if, therefore, a needle be negatively electrified and presented to the emanation, it will become coated with practically the whole of the active deposit. This may prove of service in therapeutics.

CHAPTER III

METHODS OF CONTAINING AND APPLYING RADIUM

There are several methods of containing and applying radium. The pure salt is so valuable, one milligramme at present costing £18, that the greatest care must be taken to prevent any loss. In this country, the usual quantity of bromide of radium sold is five milligrammes, put up in a small glass tube, often protected by a metal tube. This amount, five milligrammes, of the pure bromide is about half the size of a small pea ; to examine it properly a magnifying-glass must be used. It has the appearance of raw sienna or golden-brown fragments, something like brown sugar, but not so glistening or crystalline. The freshly prepared salt is white ; the colour appears after it has been kept.

The impure salt is often in the form of very small white crystals ; it is commonly mixed with barium salts, from which it is very difficult to separate. The bromide and chloride are hygroscopic and soluble, and must be kept in an air-tight receptacle ; this also

retains the emanation, which is of importance. The sulphate and carbonate are insoluble.

The radium is contained, for therapeutic purposes, either in—

(*a*) Sealed glass tubes;

(*b*) Ebonite capsules; or

(*c*) Mixed with varnish and spread out on pieces of cloth or metal.

(*a*) The sealed glass tube is, I think, on the whole the most convenient and useful container for general use, and where only one container is procured. It preserves the salt perfectly, retains the emanation, and can be easily cleaned and disinfected. As there is a risk of the tube breaking—either, as has been suggested, spontaneously from an electric spark, or from an accident—it should be enclosed in another tube of metal. This may be of aluminium, silver, or platinum, according to the quality of the radiation desired. The diameter and length of the tube should be as small as possible, both so as to localize the position of the salt inside and to permit of the introduction into the interior of tumours, fistulæ, etc. If the tube be longer than is necessary to hold the salt, the latter will accumulate at the end that is lowest down, a point to remember in making an application, for the effect will vary inversely with the square of the distance.

(*b*) The ebonite capsule consists of a disc of ebonite slightly cup-shaped on one side. The radium is placed in this cavity, and protected from air and

moisture by a thin mica window, which is held in position by a cap of ebonite. The radium covers a larger area than in the glass tube, and is convenient for application to superficial conditions. To contain the ebonite capsule and protect it from moisture, I have had a small aluminium box made by Baird, Lothian Street, Edinburgh, with a lid which screws on tightly enough to make a water-tight joint. The

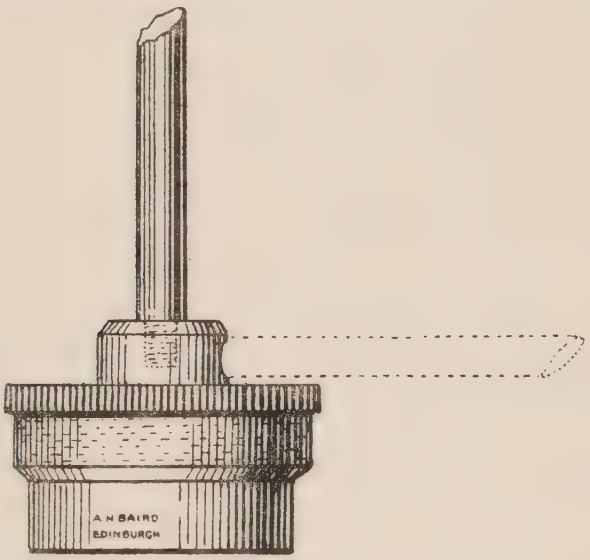


FIG. 8.—RADIUM APPLICATOR.

bottom of the box is one-fifth of a millimetre thick, so that it is practically quite transparent to the beta and gamma rays. There is a hole in the lid of the box, into which an aluminium rod can be screwed so as to facilitate applying the specimen to the interior of the mouth or other cavity (Fig. 8).

(*c*) The radium salt is mixed with hot varnish, and evenly spread on a metal or linen surface (*toile*); about 1 centigramme of the salt is allowed for

each square centimetre of surface. (The salt is usually impure.) The varnish which contains the radium is of a special kind. The metal applicator may be of copper, and of various shapes and sizes, to suit the region to which it is to be applied. On it a layer of fine metallic gauze is fixed, and into the meshes of this the radiferous varnish is run. It is by its nature stiffer than the linen applicator, and the radium is less liable to damage, but more of the alpha rays are absorbed.

The linen applicators are excessively fragile, but can be bent or folded into any shape; owing to the thin coating of varnish, the escape of alpha rays is at a maximum, but as a screen of some sort to protect the radio-active surface is almost always required, very few of the alpha rays can be utilized.

The advantage of the applicators is the great extension of the active surface. Breadth and length are increased at the expense of the thickness; thus it is eminently suitable for superficial conditions of some size—nævi, lupus, etc.—whereas with a tube a number of different applications in different spots would be required. The disadvantage is that, owing to the thinness of the radio-active layer, the beta and gamma radiation is at a minimum, and the alpha at a maximum; but the latter must be largely absorbed by the varnish, and by any screen, however thin, that may be interposed. The general result, therefore, is to weaken the effect; further, the radium is more liable to damage than when enclosed in a tube or case, so

that on the whole, in the author's opinion, this method of application is not, except in certain special cases, to be recommended.

Strength and Dose of Radium.—The first question to determine is the strength of one's preparation of radium. The French take the radio-activity of uranium as their standard, and judged by this, pure radium has a radio-activity 2,000,000 times as great. If a preparation consisted of equal parts by weight of pure radium and of some other substance, its strength would be stated as equivalent to 1,000,000; if one quarter of it were radium and three-quarters impurity, its strength would be 500,000. The latter is a usual strength in France.

But it is better, surely, to state the strength simply in terms of the amount of pure anhydrous radium bromide present; thus, if the strength were said to be 10 milligrammes, it would mean that, irrespective of its total weight, the preparation contained 10 milligrammes of pure radium bromide. Commonly, the radium preparations sold in this country are purer than those in use in France.

The radio-active strength of a preparation can be compared with that of a standard in three chief ways:

1. By the photographic effect.
2. By the fluorescent effect.
3. By the ionizing power.

The first method takes time, and does not lend itself to accurate quantitative measurement. In the second method the specimens are held in the dark at

the same distance from a platino-cyanide screen, and their relative luminosities compared; this only yields a rough guess.

The third method is the one universally adopted now. It depends on the property the radio-active bodies possess of rendering the air a conductor of electricity by producing charged carriers or ions.

If a charged body, such as an electrometer or electroscope, be approached by a specimen of radium, it will be rapidly discharged. The rate of discharge, other

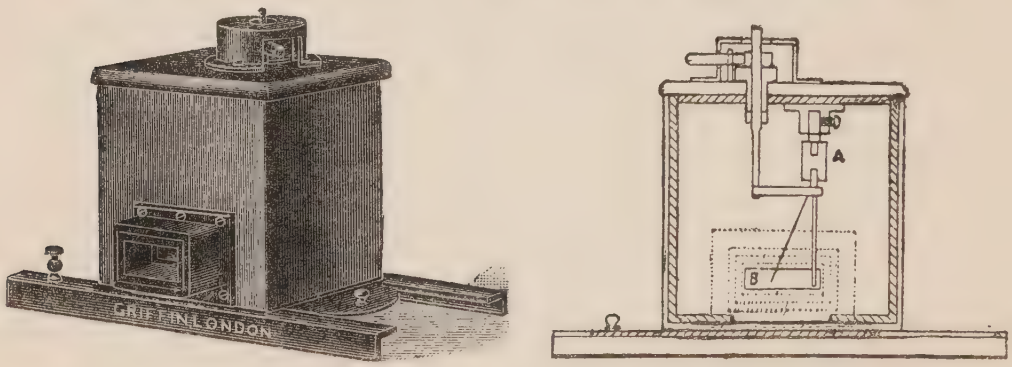


Fig. 9.—Gamma-Ray Electroscope.

things being equal, depends upon the amount of radium present; hence the rate of discharge produced by the specimen is compared with that produced by a standard preparation of radium. That is the principle of the method, but various precautions must be taken and details attended to before accurate comparisons can be made (Fig. 9).

When a specimen of radium is purchased, a written guarantee by an independent authority as to the amount of pure radium present should always be obtained, and the purchaser should contract to pay

only according to the amount of the pure salt certified to be present.

When the strength of the preparation is accurately known, the dose will depend upon this strength, upon the duration of the application, the presence of screens, the age of the patient, the nature and position of the disease, etc.

The author has already suggested (*Lancet*, December 25, 1909) that the dose ought to be stated in terms of the product of the strength of the preparation and the length of the exposure—what would be termed in an electrical measurement the "ampère hours." Thus a 10-milligramme specimen applied for one hour would be called 10 milligramme hours; applied for thirty minutes, 5 milligramme hours. If 5 milligrammes were applied for twelve minutes, it would be 1 milligramme hour, and so on. Thus a dose of 10 milligramme hours could be given by 1 milligramme applied for ten hours or 20 milligrammes for thirty minutes, etc.

By the use of screens the radiation can be altered in quantity and quality. The effect of screens is to cut off the less penetrating rays, and so to protect the skin or superficial tissues, for only those rays which are absorbed by the skin can affect it.

All the rays of radium can be cut off except the gamma rays, and the latter are few in number. The general rule for the use of screens is as follows: If a superficial condition is to be attacked, use no screen, and give a comparatively short exposure. All the rays

will now be utilized, and the effect produced will be at a maximum, especially in the immediate vicinity of the radium, because the alpha rays will predominate, and they are very powerful, but of feeble penetration. If a subcutaneous condition is to be treated, use a screen of aluminium of about half a millimetre in thickness, or a silver one of one-fifth of a millimetre, and give a longer exposure. The thicker the screen, the less the skin will be affected, but the longer the exposure. Only the beta and gamma rays will now be of use, for a thin sheet of note-paper is sufficient to stop all the alpha rays. If the disease be still deeper, use a lead screen, one-fifth or less to 1 millimetre in thickness, and give a prolonged exposure. Only the hard beta and gamma rays will get through, and they are few in number; thus the quantity and quality of the radiation has been altered. The deeper and denser tissues will now bear the brunt of the attack, and the skin and softer tissues will be almost unaffected. Very long exposures are necessary.

Wickham and Degrais point out that, when primary rays pass through a metal such as a screen, secondary rays discovered by Sagnac are emitted. C. J. Barkla has shown that the Röntgen rays behave similarly. These rays, though of feeble penetrative power, may irritate the skin. They accordingly recommend that, when a metal screen is used, a thin envelope of some non-metallic substance should in addition be interposed to cut off Sagnac's rays.

CHAPTER IV

DURATION OF APPLICATIONS

So many considerations have to be taken into account in determining the duration of applications that it is difficult to give any precise information. Account must be taken of the age of the patient, nature and depth of the disease, strength of the radium preparation, and the presence or absence of screens.

I have found that 10 milligrammes of the pure bromide in an ebonite case with a mica window can be applied for about thirty minutes to a capillary nævus on a baby's face, and for about fifty minutes to an adult's face, without provoking too much irritation. On the other hand, if a piece of silver 2 millimetres thick be interposed, the same specimen can be left on three or more hours; using a lead screen one or two millimetres thick, an eight hours' application can be made.

Care should be exercised as to repeating an application to a spot already treated, for it will produce far more reaction.

In some cases it may be an advantage, and in some it may be necessary, to maintain the radium at a little

distance (1 to 3 centimetres) from the affected part. The result of this will be to greatly weaken the effect (it varies inversely with the square of the distance), and to extend the area of the action in the same proportion. A small piece of cotton-wool, or two or three discs of blotting-paper, or a funnel-shaped leaden cylinder, will suffice for this. This method is of service in treating a port-wine stain.

Production and Use of the Emanation. — To obtain the emanation from the radium, dissolve a

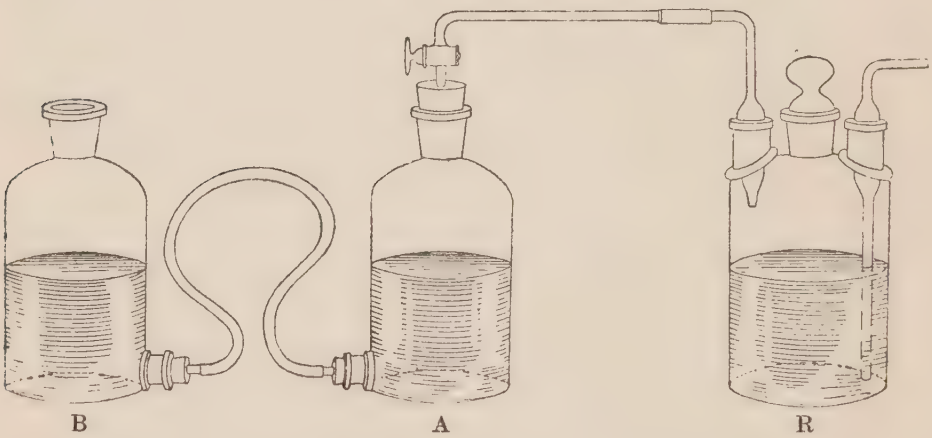


FIG. 10.—SIMPLE EMANATION APPARATUS.

little of the salt in water, and add a few drops of hydrochloric acid (if the salt be the chloride or bromide) to keep it in solution. The emanation released by the solution can be aspirated by a current of air into a receiver (A). For small quantities of radium the amount of hydrogen and oxygen set free need not be taken into account. A is a bottle filled with water (Fig. 10), connecting with another bottle, B, by an india-rubber tube. A is filled to the stopcock

by elevating B. Then, if A is connected to the radium bottle R, as in the figure, and B is lowered, the water will fall in A, and emanation and air will be sucked in. In this way A can be filled with emanated air over water, and can then be transferred as required. After removal of the emanation a fresh quantity is produced by the radium in solution, and a supply would always be ready if the radium bottle was sealed in between; but the amount would be variable, depending upon the interval between the removals.

The emanation has been used therapeutically in various ways; it has been inhaled, injected, taken in draughts, and administered by means of baths. Some natural waters are radio-active (Wiesbaden, Bath, etc.), and their efficacy may in part be due to this. It is well known that a bottled mineral water drunk at home does not produce the same active benefit that it does when drunk fresh and nascent at the spring, and this may be due to the decay of its radio-activity. This will also explain the impossibility of successfully imitating a natural mineral water; it must be made radio-active as well as of the same chemical composition.

The emanation can be enclosed in tubes and used in place of the solid salt (Jordan, *Lancet*, December 11, 1909). It must be remembered that its activity continually decreases, being reduced to one-half in four days. Jordan aspirates the emanation into a glass tube, which he seals and encloses in a lead tube of 1 millimetre thickness; this is closed at

each end and put into a rubber tube, the ends of which are closed by a silk ligature, a considerable length of silk being left attached at one end. The tube is now ready for insertion into the rectum or cervix in a case of recurrent or inoperable carcinoma. The radio-active value of the emanation tube is determined, when it is first sealed, by means of its ionizing power, and a 10-milligramme tube may be left *in situ* indefinitely. Only the gamma and hard beta rays can escape; the others are absorbed by the lead. An advantage of Jordan's method is that the loss of a tube of emanation is not of importance, but the loss of a tube of the solid salt would be very serious. A further advantage is that the whole length of the emanation tube is uniformly radio-active, while the solid crystals fall to the lowest end of the tube.

The use of the emanation in sealed tubes is not, properly speaking, the use of the emanation itself, but only of its rays and of those of the active deposit, for none of the emanation can escape; it is not in any sense comparable to the use of the emanation by injection or other introduction directly into contact with the tissues. In the latter case the emanation tends to diffuse itself throughout the tissues; it has a predilection for the glands which form an internal secretion, and especially for the suprarenal capsules. It is eliminated by the lungs and the skin, and to a small extent by the kidneys (Bouchard, Curie, and Balthazar, Congress of Medicine, Lisbon, 1906). Injections of water or of vaseline impregnated with

the emanation have been made by Radcliffe Crocker (*Medical Record*, June 12, 1909), Wickham and Degrais (*British Medical Journal*, May 21, 1910), in lupus, mycosis fungoides, and cancers, with benefit, and baths and drinks containing the emanation have been administered successfully by Strasser (*Archives of the Roentgen Ray*, No. 116, p. 332) in cases of chronic articular rheumatism, sciatica, and neuritis. Gout is also favourably influenced by this treatment.

Lowenthal (*Berlin. Klin. Woch.*, February 14, 1910) states that the emanation is chiefly absorbed by the respiratory passages, that it is of value in the treatment of chronic inflammatory processes and residues of the same, and that in therapeutic doses it is quite harmless. In order to subject the body to the permanent action of the emanation, it is necessary to apply the source of emanation several times a day, since the body gets rid of all traces through the urine and expired air within three or four hours. It is necessary in the case of baths so to construct the baths that the nose lies within the space of the bath itself, so that as much emanation may be absorbed as possible. He has found that the emanation is capable of activizing body ferments; this action would mean that the absorbing power of the body would be increased, and in this way the beneficial action on inflammatory processes would be explained. Lowenthal comes to the conclusion that specific urate-dissolving powers are to be found in mineral waters; there may be an action whereby ferments which form

and destroy uric acid may be activized by radium. It can be shown that by drinking the radium-containing waters of Baden-Baden the excretion of urea is increased by 34 per cent., while that of urates is increased by 14 per cent., as compared to the excretion when the person is drinking the same quantity of ordinary water warmed to the same temperature.

Wickham and Degrais have made an extensive use of—

1. Water rendered radio-active in the proportion of 1 milligramme of pure sulphate of radium per litre.

2. Water actually containing dissolved radium bromide of the same strength as the above.

3. Emulsions of insoluble salts of radium in paraffin and vaseline.

4. Solutions of soluble salts of radium combined with quinine, mercury, or other medicinal substance.

In all these cases the emanation is present, an element not present when the radium is enclosed in the ordinary way. In addition to the extraordinary energy of the emanation, it has been shown by Wickham that it possesses bactericidal effects on cultures of the gonococcus and staphylococcus.

The following case of large cancerous nodule of the breast treated by Wickham illustrates the use of the emulsion of an insoluble salt (*British Medical Journal*, May 21, 1910).

An emulsion of an insoluble salt of radium was made in a mixture of paraffin and vaseline. The object was to inject this preparation beneath the

nodule so as to form a stratum underlying the whole of the diseased part. When this was done we applied a radium apparatus above the nodule, so that the latter had the paraffin on its under side, and the radium apparatus above, being thereby exposed to a cross-fire to which, for various reasons, we attach importance. The nodule diminished in size and disappeared rapidly; there was no ulceration, and there has been no recurrence. The use of an insoluble salt prolongs the contact of the salt with the diseased tissues, and intensifies the action of the radiations and of the emanation.

The dose Wickham suggests of a soluble salt is the one-hundredth of a milligramme; these injections are perfectly supported. On the other hand, Radcliffe Crocker, who injected 2 c.c. of distilled water in which the emanation had been dissolved (radioactive strength not stated), mentions that the injections, unfortunately, several times caused painful swellings.

The **cross-fire method** has already been referred to in the case of the tumour treated by an injection of an emulsion of radium. The method was introduced by Wickham and Degrais, and it consists in the use of two or more specimens applied simultaneously to opposite sides of a part that it is desired to affect, so that the area between the specimens is subjected to a cross-fire. By this means, without overtaxing the skin, the interior can be exposed to a powerful radiation. Some regions are more easily

so treated than others—the nose, the ear, the cheek and lip, one apparatus being placed outside and one inside the mouth. Sometimes a specimen can be buried in a growth, and another specimen applied externally.

That **inclusion in tumours** is an extremely useful method in suitable cases I am from my own experience convinced. The tumours that are best treated by this method are those that are circumscribed and localized and of a certain magnitude. The container for the radium should be a very small glass tube enclosed in a silver tube with a screwed top (Fig. 11).

Fig. 11.—Tube and Wire for including in a Growth.

To the silver tube should be attached a soft silver wire to anchor the tube by; the dimensions of the silver tube made by Baird, Lothian Street, Edinburgh, for me are 17 millimetres long and 3 millimetres in diameter. This tube can be put into a sterilizer without damage. It can be inserted by means of a trocar quite readily to any desired depth, and the silver wire can be made fast externally by surgical plaster. The thickness of the wall of the tube is half a millimetre. I will refer in a subsequent chapter to cases treated by this method.

CHAPTER V

GENERAL EFFECT AND THERAPEUTIC USE OF RADIUM

The therapeutic use of radium is founded or based upon two chief effects which it has been found experimentally to possess :

1. A selective destructive action.
2. A general destructive action.

Effects on the Skin.—The effects on the tissues have been studied by, amongst others, Dominici and Barcat. They applied to the skin of a healthy guinea-pig a linen applicator containing 6 milligrammes of pure radium sulphate for five minutes a day for ten days. As the radium was always applied to the same spot, the dose amounted to about 5 milligramme hours.

In ten days the skin became red ; in twenty an ulcer formed, over which was a crust which fell off in four to five weeks, leaving a white cicatrix, of which the skin was depigmented, hairless, smooth, and supple. If the changes in the epidermis and dermis be more closely studied, it will be found that in about ten days' time the epithelial cells of the

epidermis hypertrophy, and that there is increased œdema. In about twenty days the epidermis is shed, and the hair follicles, sweat and sebaceous glands undergo a degeneration. In thirty or forty days the epidermis is re-formed, but the hair follicles, sweat and sebaceous glands do not reappear.

The dermis becomes in about thirty days intensely congested, and tends to pass from the adult to the embryonic condition; this is followed after a considerable interval by a return to the normal state. If the applications are too prolonged, graver changes will occur, such as necrosis of the tissues, muscles, tendons, nerves, cartilages, bones, etc.

If, on the other hand, the radium apparatus be screened by 0·5 millimetre of lead, and also by some sheets of paper and india-rubber, then it can be left on for two or three days without producing a greater effect than it produced in an hour when unscreened. Dominici calls those rays which have traversed 0·5 millimetre of lead "ultra-penetrating." They chiefly affect the deeper and denser tissues, and leave the skin and softer tissues relatively unaffected; they consist almost wholly of gamma rays. For further details reference should be made to Dominici's excellent paper in the *Archives Générales de Médecine* for July, 1909.

Effects on the Nervous System.—Danyzs, Obersteiner, Alquier, Faure-Beaulieu, London, and others, have studied this important question. The animals chosen were mice, guinea-pigs, or rabbits, and the

method of application was to insert a tube under the skin near the spine (Danyzs), or to immobilize the animal in a box in the top of which, and corresponding to the animal's cranium, was placed some radium (Obersteiner). The result of these experiments was that the animals all quickly died, particularly the young ones, from paralysis or from tonic convulsions. London observed optic neuritis in one case. In all the cases the most important and constant morbid changes were the minute hæmorrhages found in the brain and cord, and the degeneration of the endothelium of the capillaries.

Effect on the Liver.—Dr. Mills (*Lancet*, August 13, 1910) studied the action of the gamma rays on the liver of mice. The applicator used was one of 500,000 units, and it was guarded by a shield which cut off the alpha and beta rays, while allowing the gamma rays to pass through. It was applied to the anterior abdominal wall for thirty minutes in each case. (This is not explicit as regards the dose unless the weight of the salt used be added.) The mice were killed at varying intervals after exposure, and the liver examined microscopically.

The effect, briefly, on mouse liver was found to be as follows:

1. Within an hour after irradiation a transient change had commenced in the liver cells, somewhat resembling "cloudy swelling."

2. There is an early inflammatory reaction, lasting a few days.

3. There is a late inflammatory reaction, coming on in about fourteen days and lasting much longer. This was confined to the connective-tissue elements, and consisted of a marked general infiltration of the liver with lymphocytes, connective-tissue cells, and a few polymorphonuclear leucocytes, and this to a greater extent than in any of the sections taken during the few days immediately following irradiation. These changes were associated with a general hyperæmia. This, the probable histological basis of the radium reaction, is confined to the connective-tissue elements.

Effect on the Human Tissues.—If an unscreened specimen of radium be applied in a sufficient dose to the healthy skin, there will be observed in the course of a few days a red spot, which will become slightly raised and a little tender. A few flakes of epithelium may separate, and over this a scab may form, resembling, as Wickham has pointed out, an impetigo crust; this may persist for a time or be replaced by another, but it will finally fall off, leaving fresh, soft, supple skin beneath it.

If the dose be too strong an ulcer will form, which will discharge, become covered with crusts, and may finally leave a white, atrophic, depressed scar. Sometimes telangiectases follow. I have not observed any tendency to form the obstinate and painful X-ray sore.

There are certain positions in which the effect of radium is more marked. The lower eyelid, in consequence partly of the looseness of the tissues, is very

easily affected and swells, and exposures there should be short. Any exposure in the neighbourhood of the eye is very liable to produce a marked congestion of the conjunctiva; this will pass away without trouble. The nasal and buccal mucous membranes are also very sensitive. When a reaction has been produced and has passed away, care must be taken not to repeat the application to the same spot for a couple of months, for the part will be found to be extra sensitive, and unpleasant results may follow.

Thus the effect of radium is cumulative.

The histological changes produced in malignant growths by radium have been studied by Dominici, Rubens-Duval, Barcat and Faure-Beaulieu (*Arch. Gén. de Méd.*, July, 1909). In the case of lymphadenomas, the free lymphatic cells are destroyed, while the stroma undergoes sclerosis.

In the case of sarcomas, the embryonic tissue becomes converted into fibrous tissue, and the blood-vessels wither and dry up; a malignant tumour formed of embryonic tissue becomes converted into a fibroma, a benign tumour consisting of fibrous tissue. The latter undergoes retrogressive changes and shrinks, and a cure is thus brought about.

In the case of epitheliomas and carcinomas, the cancerous tissue is in part destroyed, and in part has its evolution arrested.

These are, briefly, the changes which may be looked for in growths whose evolution is arrested by radium.

Mr. Gilbert Barling, in his address in Surgery (*Brit.*

Med. Journ., July 30, 1910), makes the following remarks as to the action of radium on malignant disease, and the histological changes produced :

"Immunization by radium has a special interest. If a portion of mouse carcinoma be exposed to the action of radium for a period insufficient to produce any structural change, gross or microscopic, and this fragment be subsequently inoculated into other mice, the inoculation fails, no growth takes place. In mouse carcinoma which has already been established by inoculation, exposure to radium causes some of the tumours to disappear ; others continue to develop normally, and a few, perhaps, flourish more actively.

"Sections taken from the disappearing tumours may show hæmorrhages, but the most noticeable change is an active proliferation of the connective tissues, especially at the margin, and an invasion of the parenchyma of the tumours by young fibroblasts. As these complete their development, they contract on, strangle, and destroy the epithelial cells they embrace. We have no evidence here of a direct specific effect on the epithelium of the growth, which is found to be still actively proliferating. We have, then, after the application of radium to implanted carcinoma, a formation of scar tissue. Further experiments with radium have shown that cure of an inoculated growth exposed to its rays gives immunity to subsequent inoculations of carcinoma. This immunity is not confined to the particular area involved by the tumour, but extends to the whole body. The quality of im-

munity thus induced may have its value in increasing the resistance of the body when once a process of cicatrization of a malignant growth has been set up in the human tissues by treatment with radium.

"Turning to radio-therapy, we can immediately accept radium as curative in rodent ulcer, with this reservation, that the permanence of cure must be certified by a longer period of time than has yet elapsed in most of the cases treated. If we scrutinize the results of treating growths which are undoubtedly malignant, as shown by progressive local invasion and by secondary formations in lymphatic glands or other parts, we find much that is promising, but little that is conclusive. A profound impression is produced in many instances; malignant tumours of large extent and depth may disappear or much diminish. But the improvement and the apparent recovery is apt to be deceptive, and the subsequent return of the growth, which progresses to the death of the patient, appears to be a not infrequent experience. If a patient is the subject of an inoperable tumour, we are grateful for the benefit radium may give in the relief of pain, in the cessation of discharge, in the cicatrization of an open sore, and we should rejoice if cure seems probable. But when called upon to treat patients with operable malignant growths, are we justified in advancing radium as a substitute for excision? Personally I would not at present take this responsibility."

These remarks, coming from a surgeon of great experience, and who is without bias in favour of radio-active methods, are of great value.

Radium has, as already mentioned, a selective destructive as well as a general destructive action, and it is the former action which gives it its chief value. In its power of selection it takes complete precedence of other caustics; this, added to its extraordinary powers of penetration, enables it to seek out and destroy elements to which it is inimical—*e.g.*, neoplasms, angiomas, etc.—while passing by and leaving unharmed the normal tissues. To this must be attributed the excellent scars left by radium treatment.

CHAPTER VI

CHIEF DISEASES IN WHICH RADIUM MAY BE USED

The chief diseases in which radium has proved of service are as follows: Rodent ulcer, angiomas, warty growths, lymphadenomas, malignant growths, leucoplakia, lupus erythematosus, lupus vulgaris, cheloids, tubercular glands, spring catarrh, corneal ulcers, pruritus, syringomyelia. The emanation has been used (p. 29) in simple and gonorrhœal rheumatism, in rheumatoid arthritis, in neuralgia, and in catarrhal affections of the respiratory tract. In France they prefer to use it in baths and in poultices containing radiferous substances; in Germany they administer it by ingestion and inhalation.

Of all serious diseases, rodent ulcer is the one that is the most amenable to radium treatment. The experience of many cases has taught me that in superficial or deep rodents, provided the bone and cartilages are not destroyed, radium properly applied acts as a charm. The latter is quite a proper term, for under the influence of radium, without any opera-

tion, bleeding, suffering, or even discomfort, the hard edges of a rodent will melt down, the surface will fill up, and there will be a complete *restitutio ad integrum*.

As a rule, beyond what is necessary to protect the radium, no shield is required. The use of a shield would prolong the treatment without corresponding advantage. If the radium is in a glass tube, apply it directly to the surface of the ulcer, and fix it in position by a strip or two of plaster. The patient, if the ulcer is on the face, should be recumbent. See that the tube is so placed that its lowest end is against the ulcer, as the radium will naturally gravitate to that end. If the radium is in a capsule with a mica window, wrap a thin piece of india-rubber round the capsule, and apply it directly to the ulcer.

If the area of the ulcer be greater than the active surface of the radium, successive applications must be made in different places until the whole has had a sufficient dose. Or the radium may be supported upon some cotton-wool at a little distance (a few millimetres) from the surface of the ulcer; this will extend the area of the radio-active effect, but diminish its intensity, so that longer exposures will be necessary. If the rodent be near the eye, the latter must be protected by a shield of lead-foil; if in spite of this a conjunctivitis be set up, no anxiety need be felt, for the inflammation will be transient. What dose should be given? That depends upon the position, duration, and depth, of the ulcer, the age of the patient, etc.,

but for a superficial rodent on the nose you may begin by a dose of 10 milligramme hours for each position—that is, the application of 10 milligrammes of pure radium bromide for one hour, or what is equivalent to that (*vide* p. 23). After the whole area of the ulcer has received this dose, interrupt the treatment for three or four weeks or longer, and then recommence, being guided by the effect already produced.

If the ulcer be deeper and more serious, give longer exposures without waiting to see the effect. Remove all scabs and clean the surface before applying the radium.

After-Treatment.—This is simple. As a rule no after-dressings are necessary; leave the part alone. If the surface be suppurating, wash with a mild antiseptic several times a day. If it be dry and itchy, apply a soothing ointment. If possible, do not interfere with the scabs which will form; in three to six weeks' time, when they come off, the surface will probably be healed.

Now to refer to some of the cases I have treated.

Case 1.—A male, aged forty-six years, consulted me in 1906; he was suffering from a rodent ulcer on the nose. It was of the size of a sixpence, punched out, and of about a year's duration. He was treated by the X rays, applied two or three times a week for about three months, but without much benefit. Radium was now tried, and eighteen applications of twenty minutes each (six hours in all) caused it to heal over with a soft, supple scar. In this case

5 milligrammes of impure radium bromide of an activity of 300,000 were used. Expressed in proper terms, the dose was about 4·25 milligramme hours. He has since had, at intervals of about six months, three recurrences, each of which has yielded at once to one or two fresh applications. He is a working man who cannot afford the time to have it thoroughly treated.

Case 2.—A patient, aged about fifty years, recommended to me by Dr. M. Burnett, consulted me about a rodent ulcer of six years' duration, placed close to and invading the inner canthus of the eye. It was a little smaller than a sixpence. I shielded the eye with lead-foil, and gave him in all five hours' treatment with 10 milligrammes of pure radium bromide (50 milligramme hours); no shield except a thin piece of parchment paper was used. In one month's time he was completely cured, and there has so far (eighteen months) been no recurrence. This case and the preceding one illustrate the necessity for pushing the treatment beyond what would otherwise seem to be required, if a recurrence is to be avoided.

Case 3.—A more serious case, in an older gentleman, recommended to me by Dr. G. Carmichael. The ulcer measured $2\frac{1}{2}$ by $1\frac{3}{4}$ inches, was excavated, had very prominent raised edges, and extended from the nose to the inner canthus. It was of many years' duration. It was treated with 10 milligrammes of pure radium bromide, enclosed in an aluminium box one-fifth of a millimetre thick, for four hours weekly. Improve-

PLATE IV.

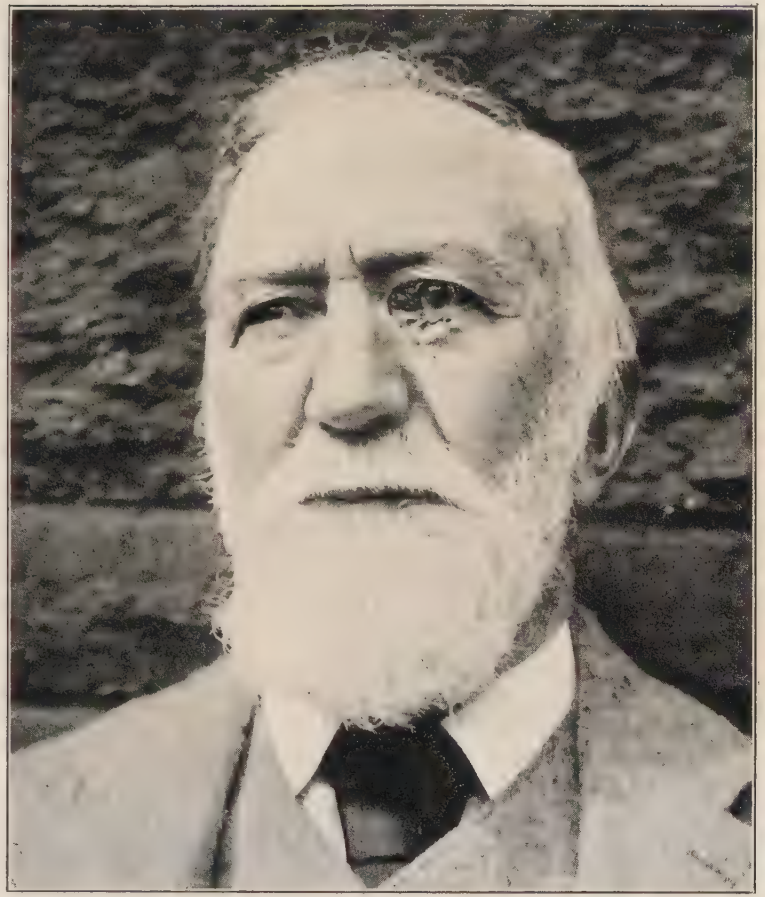


FIG. 12.—RODENT ULCER BEFORE TREATMENT.

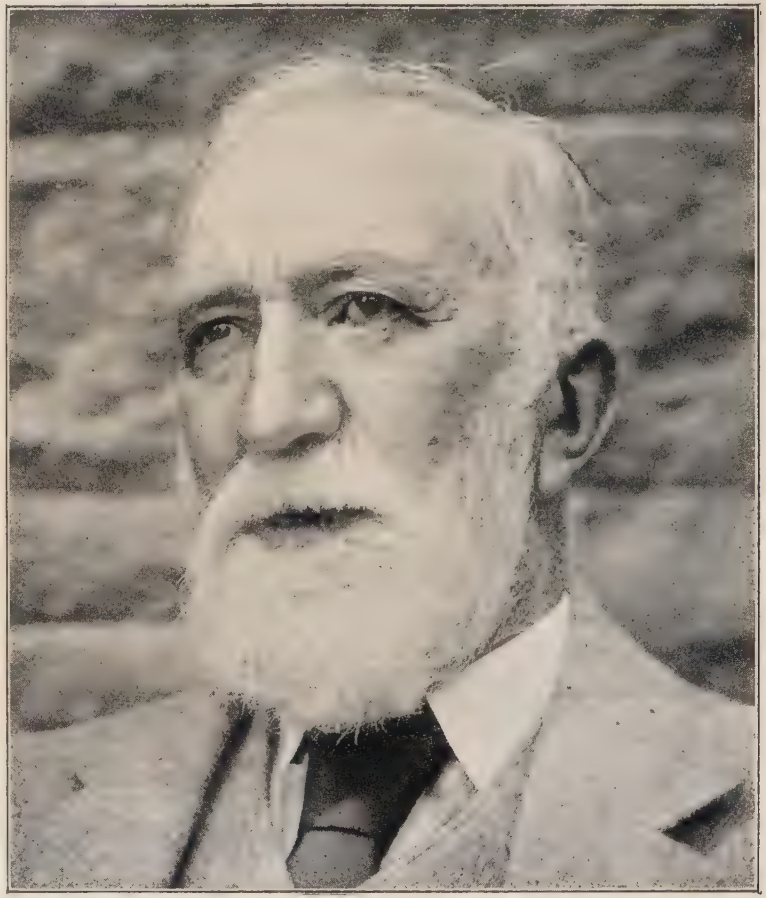


FIG. 13.—RODENT ULCER AFTER TREATMENT.

To face page 44.

ment was slow but steady, and now, after a total of eighteen hours' exposure (180 milligramme hours), the ulcer is completely healed, and covered with a beautifully supple skin. The actual treatment occupied about six weeks, but the full improvement was not noticeable until many months had elapsed. This was a large ulcer to attack with a radiating surface of radium of only 1 centimetre in diameter; each application was made to a different spot until all had been treated, when they re-exposed. In Paris they would, no doubt, have treated this case with a radium plaster, so as to attack its whole surface at once; but, as I have already explained in a previous chapter (Chapter III.), the density of the radiation would have been much weaker, and I doubt whether a quicker result would have been obtained than by my method of applying the whole quantity to a small area at a time.

Case 4.—A gentleman, aged seventy-six, recommended by Dr. George Mackay. The patient suffered from a rodent ulcer which had partially destroyed the inner canthus of the left eye, and was extending along the lower border. It was of twenty-three years' duration, had been burnt four times, and was now extending rapidly (Fig. 12). After a photograph had been taken, treatment with radium was begun. The eye having been protected by a piece of lead, 10 milligrammes of the pure bromide were applied in an aluminium box directly to the surface of the ulcer. The rays had to traverse a mica window and a piece of aluminium one-fifth of a

millimetre thick. This was in May; improvement began at once, and in two months' time, after fourteen and a half hours' exposure (total 145 milligramme hours), the ulcer was healed. Another photograph was now taken (Fig. 13). This serious case affords an example of the rapidity with which radium can act in suitable conditions. The scar tissue will continue to improve for some time.

For rodents which are situated on the mucous membranes or on the cutaneo-mucous surfaces, the ultra-penetrating rays of Dominici may be recommended. The radium rays must be filtered through 0·5 to 3 millimetres of lead, and also through several folds of paper and a piece of india-rubber, in order that Sagnae's rays (page 24) may be cut off. Only the hard beta and the gamma will get through, and very long exposures of several hours are required. This greatly adds to the difficulty of treatment.

PLATE V.

Fig. 14.—Capillary Nævus before Treatment.

Fig 15.—Capillary Nævus after Treatment.

CHAPTER VII

ANGIOMAS

Angiomas can be very successfully treated by radium. The most amenable are the capillary nævi of infants, and the most troublesome are port-wine stains in adults.

The treatment of a capillary nævus in a child is very simple, and the result very satisfactory. Administer a dose of about 5 milligramme hours, as a rule without a shield, and leave it alone for six weeks, when it will probably be found to have completely disappeared. If it has not, a second dose can be given.

Case 5.—A baby, aged six months, recommended by Dr. James Graham. On the right side of the baby's nose was a capillary nævus about the size of a sixpence. This started as a small spot, and has grown rapidly. Ten milligrammes of pure radium bromide were applied without any shield except a mica window for twenty minutes (total 3·3 milligramme hours). Three days later a tiny white speck appeared in the middle of the nævus, and very slowly spread over its whole surface. Now, nine months afterwards, the

position of the nævus can scarcely be distinguished from the surrounding skin (Plate V.).

Nævi of the Scalp.—Owing to the destructive action of radium on the hair follicles, it is open to question whether this agent should be used in the treatment of nævi on the scalp, as a bald spot is apt to be left.

Erectile angiomatous swellings in children yield rapidly to radium treatment; séances of 5 to 10 milligramme hours can be administered either without or with a shield; the latter is usually unnecessary, for the application of the whole radiation will in these cases rarely provoke much skin reaction.

Pigmentary nævi can be removed by the destructive action of radium. The exposure must be regulated by the depth of the affected tissue, but sufficient doses must be given to destroy the pigmented skin and the hairs which are commonly present. After the whole surface has been so attacked, a long time should be allowed to elapse for the inflammation to subside and for the results to become manifest. This may take some months; treatment can then be resumed to the parts which require it. The patient should be warned of the duration of the treatment, and of the disfiguring inflammation which will be set up. The results of the treatment from the æsthetic point of view are excellent.

Case 6 (Plate VI.).—A boy aged five, recommended by Dr. P. H. Ferguson, was brought to me in April, 1910, on account of a large brownish-black pigmented nævus of the left ocular region. This was noticed

PLATE VI.

FIG. 16.—PIGMENTARY NÆVUS BEFORE TREATMENT.

FIG. 17.—PIGMENTARY NÆVUS AFTER PARTIAL TREATMENT.

To face page 48.

at birth, but it has since been growing. It now measures about 2 inches in each direction. A photograph was taken on April 19, 1910. Ten milligrammes of pure radium bromide were applied in an aluminium box direct to the patch, and kept on for an hour; the next day they were applied to another spot, and so on every day or two until the whole of the patch had been treated. In one month's time he had had 120 milligramme hours (10 milligrammes for twelve hours). All treatment was now interrupted, and the reaction produced observed. This was excessive, attended by suppuration and scab formation, which did not clear up for about two months, but then a great improvement was remarked. A few spots still require treatment.

Angiomatous tumours in adults, whether infiltrating or elevated above the surface, are also amenable to radium rays, and are to be treated on the general principles already studied; but a reference must be made to the best method of dealing with port-wine stains. There is no difficulty in removing this disfiguring affection by the destructive action of radium rays; the difficulty is, to know when to stop so as not to overdo it. The results of overexposure are white atrophic areas depressed below the level of the surrounding skin, and looking a little like smallpox pits, and telangiectases (more rarely). From a considerable experience of the treatment of this condition, both with strong and weak specimens of radium, I think the most prudent method, considering the importance of

the appearance afterwards, is to apply weak specimens only. Select a particular area and give it a dose of about 1 milligramme hour, and await the result, and remember that weeks must elapse before this stage is reached. In the meantime you can be treating other spots in the same cautious way. The radium plasters would be of service in dealing with extensive areas, for they yield as a rule a weak radiation, and their use would insure an even application.

If your specimen be one of 5 milligrammes of the pure salt in a glass tube, support it upon some cotton-wool or a thin piece of cork at a few millimetres from the surface of the spot you desire to attack; this will have the effect of increasing the area, but of diminishing the intensity of the radiation. Warn the patient of the duration of the treatment, and arrange for a visit once a week or fortnight.

Case 7 (Plate VII.).—A female patient, aged twenty-four, recommended to me by Professor Alexis Thomson. On the left side of the face there was a very large port-wine stain, roughly divided into three parts. It extended from the roots of the hair above the ear down to the level of the mouth, and it was about 4 inches in breadth; it was almost entirely superficial. Many remedies had been tried unavailingly. A photograph of the face was taken on April 26, 1909, and treatment was then begun. Ten milligrammes of pure radium bromide, protected by a mica shield and a sheet of tissue-paper, were applied for from half an hour to an hour at a time to different areas; no area

PLATE VII.

FIG. 18.—PORT-WINE STAIN BEFORE TREATMENT.

FIG. 19.—PORT-WINE STAIN AFTER PARTIAL TREATMENT.

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PLATE VIII.

FIG. 20.—PORT-WINE STAIN BEFORE TREATMENT.

FIG. 21.—PORT-WINE STAIN AFTER PARTIAL TREATMENT.

To face page 50.

was exposed a second time until all reaction had passed off. The applications were at first sometimes followed by headaches. When subsequent applications were made to a spot which had been previously treated, a more intense reaction followed. This patient has had a total of fifty-five hours' exposure, or 550 milligramme hours, spread over many months—in fact, over more than a year—but she has been irregular in attending. The result is a great improvement. Over about half the original area the natural colour of the skin has been restored; it is difficult in some places to make out the original extent of the disease. In other places white atrophic spots have appeared, which might have been avoided had weaker specimens only been employed.

In treating port-wine stains, a good maxim is, "Surtout point de zèle." The photographs show the value of radium treatment in this intractable condition.

I will now refer to a case of a similar nature treated by weak preparations only of radium.

Case 8.—A female patient, aged twenty-five, was admitted to the Electrical Department in January, 1910. On the right cheek there was a port-wine stain of a dark purple-red colour; it was congenital in origin, and measured 2 inches in length and $1\frac{1}{4}$ inches in breadth (Plate VIII.). There were also similar stains on the neck and temple. A photograph was taken before treatment was begun. The patient was treated by weak preparations of radium containing either

0·7 or 1 milligramme of the pure salt. She attended twice a week, and had one to two hours' exposure on each occasion; no shield was used except the glass wall of the containing tube. During the exposures she read a book, and during the whole course of the treatment she has experienced no inconvenience whatever. She has now had six months' treatment and a total of 95 milligramme hours (1 milligramme applied for ninety-five hours). The result, as will be seen from the photographs, is a great improvement. The dark colour has been gradually discharged without the production of any whitish atrophic patches.

Warty Growths.—Warts can be readily removed by radium rays. Apply a 10-milligramme-hour dose to a small wart, and in three weeks' time it will probably have disappeared, sometimes from a sort of absorption, and sometimes by an inflammatory process which causes a shedding of the wart. The inflammatory process may be a little painful—hence it is well to commence by a small dose. Also refrain from treating too many warts at one time on the same hand.

Case 9 (Plate IX.).—On one occasion I treated four warts on the right hand of a lady, giving each a dose of 10 milligrammes, for one hour, of pure radium bromide—10 milligramme hours—in a space of two days. In about a fortnight she wrote to say that nothing had followed, and that no change had occurred, and that she feared that the treatment had failed. In another week's time she wrote again to complain of the effect of the treatment; the warts were swollen

PLATE IX.

FIG. 22.—WART BEFORE TREATMENT.

FIG. 23.—WART AFTER TREATMENT.

To face page 52.

PLATE X.

FIG. 24.—PAPILLOMA BEFORE TREATMENT.

FIG. 25.—PAPILLOMA AFTER PARTIAL TREATMENT.

To face page 52

and sore, two had dropped off, leaving a raw surface, and she could not shake hands or write. The irritation passed off in a few days' time, and the warts have not recurred. No shield should be used in treating a wart.

Papillomata—Case 10 (Plate X.).—A patient, aged seventy years, recommended by Dr. McEwan, was admitted to the Electrical Department of the Royal Infirmary on October 15, 1909. She was suffering from a papillomatous growth on the left cheek. Ten years previously a similar growth had been removed, and there had been no recurrence for some seven months. During the last year the growth had extended rapidly. It now measured 2· inches by 1½ inches, and it projected about half an inch from the surface of the skin. Treatment with radium was begun on October 15, and on November 25 of the same year the patient was discharged, the growth having disappeared. The total exposure was 43·3 milligramme hours.

CHAPTER VIII

MALIGNANT GROWTHS AND ASSOCIATED CONDITIONS

The benefit that can be derived from the use of radium in the treatment of malignant growths depends more upon the nature of the growth than upon its size.

Thus, as we have seen (p. 41), rodent ulcer yields readily to the action of the rays. Lymphadenomas and sarcomas are also readily influenced, but not to the same extent as rodents, but the true carcinomata are less amenable. The position of a growth plays an important part in the prognosis. Those that are superficial, localized, and circumscribed, are the most favourably situated, for then they can be attacked on all sides and from the interior (Case 11); deeply situated growths, as in the thorax or abdomen, are with difficulty affected except by considerable quantities of radium well shielded to protect the skin; they would be best treated by the insertion of a tube of radium by a surgical operation.

Growths affecting the mucous membranes are less amenable than those affecting the skin; thus, if an

epithelioma of the lip or cheek should spread or perforate to the buccal cavity, it will be more refractory to radium rays. Where there is extensive infiltration and glandular involvement, the prognosis is necessarily more serious. There is not often an opportunity of treating early cases of malignant disease with radium, for in the present state of our knowledge operation, where possible, offers the best chance of success. Dr. Louis Wickham of Paris made the following general remarks regarding the use of radium in cancer at the July meeting of the British Medical Association, 1910: "The chief interest of radium was in its power of selection. In this rôle it acted as a caustic of special subtlety, seeking out those elements which it wished to destroy. All tissues were not ground for the selective action of radium, but cancer, angioma, cheloid, etc., presented a particularly favourable field." The lecturer summed up his conclusions as follows:

"1. The excellence of result depends on the possession of great experience and a large quantity of radium.

"2. In the great majority of cases surgery should be associated with radium. If the radium therapeutist is in presence of a case of grave cancer, he should first consult the surgeon, so that the patient may not be deprived of the prompt help of surgery. If the surgeon is in the presence of a case difficult to operate in, he should have recourse to radium, to prepare the ground and diminish the virulence,

and again after the operation, to consolidate the tissues. The surgeon can also in his turn prepare the ground for radium, and his help should be utilized for making the perforations, incisions, partial extirpations, etc., which permit the diminution of the thickness of tumours which the rays have to traverse, and to render the application of radium introduced into the wounds more effective. Surgery should be employed to prepare the way for radium in making artificial orifices, or to conduct the tubes of radium to the tumours through the natural orifices. Surgery must discover the operations for permitting the radium apparatus to penetrate into tumours which are inoperable and deep-seated.

"3. The tumours must be deluged with rays; for this, very powerful apparatus is used in opposition, either in cross-fire, or on the exterior surface of the tumour, or by perforations multiplied in the interior of the tumour. If there be any skin, mucous membrane, bloodvessels, or nerves, to protect, there must be placed between the apparatus and the tissues protective screens, whose thickness will vary in proportion to the power of the apparatus and the duration of the application; but on the quick of the tumours the apparatus can be employed with very light filters, to utilize the maximum quantity of rays.

"4. Like surgery, radium does not affect the general state, neither does it prevent recurrences and metastases. (This is opposed to Mr. Gilbert Barling's experiments, p. 38.) It must be clearly understood

that the term 'cure' should be but rarely used, and then should only be attributed to the regression of the tumour itself. To say that radium 'cures' patients suffering from cancer is to risk deceiving the patient and doctor.

"5. Even in its thus limited rôle radium is a precious weapon. In our struggle against cancer we are so inadequately equipped that any supplementary arm, new and well proven, even were it weak—which radium is not—should be regarded as a precious beneficent aid, and taken into serious consideration."

Chevrier, the Paris surgeon (*Arch. d'Élec. Méd.*, July 10, 1910), agrees that radium, which cures without cicatrix, is the treatment of choice in simple cutaneous epitheliomas without invasion of the glands. By this he probably intends rodent ulcers.

The infiltrated cutaneous variety, which affects the glands, presents a more grave state of affairs, and he questions the prudence, in spite of its apparent efficacy, of simple radium-therapy as the only mode of treatment. But in mucous and glandular epitheliomas he is altogether sceptical. The capital objection to radium applied in these cases, in his opinion, is the very large number of living cells, extraordinarily active and proliferating, which it is expected to destroy. He pleads for the surgical removal of the tumour, and for the use of radium only as an agent to destroy the microscopical residues which always escape the bistoury, and later give rise to relapses. In the operation wound corresponding to

the tumour and to the glands extirpated, he would place radiferous tubes for a varying length of time, according to their intensity. In the case of a cancer of the breast, he would leave two very active radiferous tubes, one in the central part of the wound, and the other at the summit of the axilla. Further, he would give applications from ultra-penetrating apparatus on the supraclavicular and subclavicular regions on the following days. He repeats finally that the employment of radium as the only therapy against a mucous and glandular epitheliomatous tumour must be renounced, and that the alliance of radium with the bistoury—the former to prevent relapses after surgical extirpation—assures for radium a more modest rôle, but one of certain efficacy.

Case 11.—The following notes refer to a case of recurrent sarcoma of the back which was treated by me in the Electrical Department of the Royal Infirmary, Edinburgh, by the cross-fire method.

Sarcomas.—A female, aged fifty-six years, recommended by Dr. D. Huskie, of Moffat, and Mr. C. Cathcart, was admitted to the Electrical Department on January 10, 1910. She was suffering from a sarcoma of the back (Plate XI.). About five years ago Dr. Huskie removed what appeared to be a sebaceous cyst from her back. This was, unfortunately, owing to an accident, not examined microscopically. A year later Mr. Cathcart removed a recurrent growth, which proved to be a sarcoma, and again last year he removed a second recurrence. On admission there

PLATE XI.

FIG. 26.—SARCOMA, FOURTH RECURRENCE, BEFORE RADIUM TREATMENT.

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was a swelling on the back, above the site of operation, about the size of a large plum. During the next fortnight she had seven applications of the X rays, from which she received some benefit, and she then returned home. On May 27, 1910, she returned because the growth had increased greatly in size. The growth was now photographed, and a cast of it was taken by Mr. Cathcart. It was now about the size of a large teacup or bowl, and was raised $2\frac{1}{2}$ inches above the surface; it measured 6 inches in length and 6 inches in breadth.

A silver tube 0·5 millimetre thick, containing 5 milligrammes of pure radium bromide, and having a silver wire attached to it, was inserted by means of a trocar into the growth. After remaining for seventy-two hours in one position, it was moved along the tract a little by means of the wire; it was left in this position for forty-eight hours, and then taken out and reintroduced into another part of the growth, where it rested for eighty-six hours; total internal application, 5 milligrammes for 206 hours, or 1,030 milligramme hours. Meantime I applied daily externally a specimen of 10 milligrammes of the pure bromide, shielded by 0·5 millimetre of silver to save the skin. Care was taken not to reapply this twice to the same position. The neoplasm was now between two fires, with the result that it ceased to increase and that the stinging pain disappeared. After fifty hours' external application—500 milligramme hours—all treatment was suspended. Seventeen days later, as no excessive reaction

had been produced, 5 milligrammes of the pure bromide were again introduced into another part of the growth, but this time enclosed in an aluminium tube only. It remained in for 240 hours, but its position was twice altered. The dose was 1,200 milligramme hours, but the effect was much greater because the silver shield had been omitted. On July 24 the tube was extracted, by making an incision, by Mr. Cathcart, as the silver wire had broken. The patient had now had in all 500 milligramme hours externally and 2,230 milligramme hours internally. The tumour was now much reduced in size, and also firmer. The skin was reddened in places with a few slight scales, but had escaped all serious irritation. The patient felt better, and looked better and stouter. She was now sent home for a rest.

On September 23, eight weeks and three days later, she returned; she stated that she had been a great deal better during the holidays, and that her shoulder had felt easier until a week ago, when it began to feel less comfortable. The growth, on comparing it with the cast taken on May 27, was found to have the same over-all dimensions—6 inches by 6 inches—but was slightly more prominent and nodular in two places (these places were the farthest away from the points where the radium had been buried), and slightly flatter and more shrunken in regions nearer the graves. Treatment will now be resumed by the insertion of tubes of radium and by the external application of radium. Among the chief points of

interest in this case are: (1) The remarkable effect of the treatment in delaying the growth of the tumour; in the previous six months the tumour (fourth recurrence) had grown to its present dimensions; in the succeeding four months, two of radium treatment and two of rest, it had practically ceased to increase. (2) The innocuous character of the treatment; the radium, screened by 0·5 millimetre of silver, lay first for eight days, and then, screened by 0·3 millimetre of aluminium, lay for ten days, in the tumour—total, eighteen days fourteen hours—and yet it produced no sensible rise of temperature or visible necrosis. In tumours other than sarcomas which I have treated similarly by the introduction of a tube of radium, but for shorter periods, considerable necrosis may follow the applications.

The following case illustrates the use of radium in the interior of the mouth:

Case 12.—A male, aged fifty years, recommended by Professor Alexis Thomson, was admitted to the Electrical Department of the Royal Infirmary on August 13, 1909, suffering from a neoplasm, probably of a transition type, involving portions of the hard and soft palates. He had been ill for about a year, and a full course of iodides and of mercury had been taken without benefit. Professor Thomson had on two occasions excised portions of the growth for microscopic examination, without clearing up the diagnosis. Had the diagnosis been that it was definitely cancerous, he would have attempted to

remove it, but failing such a diagnosis the operation seemed too serious a one to subject the patient to. This patient was at first treated with the X rays by a tube, whose prolongation could be inserted in the mouth. After twenty applications had failed to produce any benefit, radium was tried. Ten milligrames of pure radium bromide were placed in the aluminium applicator described on p. 19, and by means of the rod were maintained by the patient against the growth for about an hour at a time. Improvement began at once, and after ten hours' exposure—total, 100 milligramme hours—I sent him to be re-examined by Professor Thomson. The latter wrote on November 25, 1909: "Decidedly improved, especially on the left side, where healing appears to have started."

The patient continued to attend for radium treatment once a week, and sometimes less often, until the August holidays, when for eight weeks all applications were interrupted. During this interval the growth resumed activity, and when an exploratory incision showed that it had taken on a definitely epitheliomatous character, Professor Thomson removed it by operation. There can be little doubt that the radium treatment kept this growth in check.

I have used radium with temporary benefit in certain epitheliomas of the face, lips, and glands of the neck, but where perforation into the mouth has occurred the remedy has failed. In all cases where it has been possible to insert and leave in a tube of radium, the beneficial effect has been greater.

This would lead one to conclude that very much longer exposures and stronger doses are indicated in malignant disease. When a tube of radium is inserted in a tumour, we may liken it to a little sun, which is all the time and in every direction projecting its beneficent rays, all of which must pass through the growth; but the rays of radium are superior to the light rays of the sun in one respect, and that is in their power of penetration. They are not stopped by the first layer of cells, for the harder rays traverse the whole body. If radium can be applied externally as well, so much the better, for the neoplastic cells will now be subjected to a cross-fire. In applying radium externally, it must be remembered that we are only utilizing a very small portion of its radiation, the greater part escaping from the back and other sides of the specimen; but when it is buried internally, then none of its radiation can escape without traversing the neoplasm. Where the external dimensions of the growth are large, it would be well to apply the X rays as well as radium. Where the skin is intact, both forms of radiation must be filtered, the X rays through 0·5 millimetre of aluminium, and the radium through 0·1 to 0·5 millimetre of silver.

For epitheliomas of the cutaneo-mucous or mucous surfaces Dominici recommends the ultra-penetrating rays (*vide* p. 34), obtained by screening the radium through lead of half to several millimetres in thickness, several sheets of paper, and an envelope of india-rubber. Unshielded radium, which gives remark-

able results in cutaneous epitheliomas, is dangerous for cancers which encroach on the buccal mucous membrane, as they may stimulate rather than arrest their development. Gaucher has pointed out that the same rule holds for certain caustics. In Dominici's opinion, the use of the ultra-penetrating rays, and the prolonging of their action on the diseased tissues, is especially suitable for epitheliomas of the mucous membrane. This opinion, with which Professor Gaucher is in accord, is confirmed by the rapidity with which tumours of the labial mucous membrane disappear under the influence of the ultra-penetrating rays, and by the tolerance of the tissues of the lip towards these rays. These facts have led Dominici to try the same method of treatment in cancer of the tongue. The results so far obtained at the St. Louis Hospital seem to show that malignant neoplasms of the tongue are also amenable to radium-therapy ("Diseases of the Skin," E. Gaucher, p. 295).

Dominici is of opinion that the least penetrating rays, the alpha and the soft beta, cause most alteration in the healthy tissues, and that the most penetrating rays, the gamma and the hard beta—that is, the least alterative—have an extremely powerful therapeutic action.

CHAPTER IX

TREATMENT OF DEEP-SEATED CANCERS—LEUCOPLAKIA—LUPUS—LUPUS ERYTHEMATOSUS—CHELOIDS

Deep-seated cancers can only be satisfactorily attacked by the introduction of tubes of radium; for this purpose the natural passages, or sinus, or incisions made by a surgeon, will serve. The glass tube containing the radium salt must be enclosed either in an aluminium or silver or platinum or gold tube, the metallic thickness being from 0·2 to 0·5 millimetre. To this a soft silver wire should be attached, to enable the tube to be withdrawn. Dominici and Cheron cite a case of lymphadenoma of the parotid region, the region being completely hypertrophied, and the tumour encroaching upon the temporal region above and the maxillary region in front. It was judged to be inoperable. An incision with the bistoury was made in the centre of the neoplasm, and a gold tube containing 5 milligrammes of radium bromide, of 4,300 activity, was introduced (unless there is a misprint here, the dose is very small, and equal to about 0·017 milligramme). The apparatus was maintained in position for five

days, when there was evident improvement, and at the end of seven weeks this improvement had become a definite cure. This patient was shown before the section of Radiology at the British Medical Association meeting in London, July, 1910.

Another case shown by these gentlemen to the Radiology section was that of a deep sarcoma of the neck. In July, 1907, two years before treatment was begun, the tumour appeared as a small nodule under the right lower jaw, increasing very rapidly in size in the previous three months. At the time of examination it was purplish in colour, with blood and serum oozing from several orifices. Histological examination showed its structure to be that of a pure embryonic sarcoma. In July, 1909, three tubes, each containing 0·5 milligramme of pure sulphate of radium, with a silver sheath 0·5 millimetre thick, were introduced for forty-eight hours. Seven weeks later a deep, indurated, flat mass represented the tumour, which, however, recurred, or, rather, again showed active growth, in November, 1909, when the treatment was repeated with apparently definite success. A small nodule now existed near the cicatrix.

Cancers of the stomach can only be really ameliorated or cured by having tubes directly introduced into them after laparotomy. Of all the neoplasms of the alimentary canal, those of the rectum are the most amenable to radium. As to cancers of the buccal mucosa, these, save in the labial zone, are not generally ameliorated or cured by surface applications of

radium. In cancers of the breast—except in cases which are operable, when, of course, surgical measures are indicated—the authors state categorically that the treatment of choice is the introduction of radiferous tubes in silver, containing 5 to 10 centigrammes of pure sulphate of radium, into the neoplastic mass. Each application lasts from twenty-four to seventy-two hours. The embedded radium effect may be aided by surface applications of radium in varnish (*British Medical Journal*, June 11, 1910). Dominici has also employed injections into the cancerous mass of $\frac{1}{100}$ milligramme doses of radium sulphate suspended in normal saline solution. (See also p. 30 for Wickham and Degrais' methods.)

Recurrent Epithelioma of the Cervical Glands—Case 13.—A male patient, aged forty-one, recommended by Professor Alexis Thomson, was admitted to the Electrical Department of the Royal Infirmary, Edinburgh, on July 4, 1910, for radium and X-ray treatment. Fifteen months before, Professor Thomson had removed a small epithelioma of the tongue, and had also taken away some of the glands of the neck. For a year he was well and went about his work, but about three months ago he noticed a lump behind the angle of his jaw on the right side; this increased in size rapidly. There is now a very hard large mass lying between the angle of the jaw and the sterno-mastoid, filling the upper part of the neck on the right side. Patient suffers greatly from a constant pain behind the growth. Treatment was begun by

the external application of 10 milligrammes of pure radium bromide filtered through 0·5 millimetre of silver. As this seemed a suitable case for the internal introduction of the salt, Professor Thomson at my request inserted, but not without difficulty, owing to the extreme hardness of the growth, a tube of 5 milligrammes of pure radium bromide contained in a silver tube 0·3 millimetre thick. By the next day the constant pain had disappeared. In six days' time the tube was removed; total internal exposure, 144 hours of 5 milligrammes; this is equal to 720 milligramme hours. After this X rays were applied externally three times a week. A fortnight later the swelling was found to be smaller and softer, and the patient could turn his head more easily. An ulcer formed below, and some of the matted glands broke down and discharged, while the others became smaller and softer.

The patient, however, continued to lose strength, and died about a month later, rather suddenly, probably from pressure on the pneumogastric nerve. This case illustrates the risk there may be of setting up necrosis and discharging cavities by the continued action of radium, though shielded by silver, in epitheliomas. The dose was less than one-third that administered to the case of sarcoma narrated previously. The necrosis may, of course, not have been wholly, or even partly, due to the treatment, but it certainly followed it.

Leucoplakia, Lupus, Lupus Erythematosus, etc.—The French authorities recommend radium in

leucoplakia; I have had experience of three cases so treated.

Case 14.—The first one was a lady of fifty, a patient of Mr. J. Struthers. She had suffered for the last year from this condition, and also from ulcers at the front of the tongue. There were two chief patches of leucoplakia on the dorsum, and an ulcer at either side. For the last three months the patient had been unable to eat without pain, and had been obliged to confine herself to soft food well soaked. After two applications, of one hour each, of 10 milligrammes of the pure salt, equivalent to 20 milligramme hours, she returned to say that all discomfort in eating had disappeared, and that she had again been able to enjoy hard food. The ulcers healed rapidly, the leucoplakia slowly; every application produced a feeling of relief, and made her tongue feel more natural. She had in all a dose of 127·8 milligramme hours, and she returned three months later to express her gratitude and to show her tongue, which was in almost a normal condition. Mr. Struthers wrote to say how glad and interested he was to see how well the patient was. "The tongue is certainly very much better than when I saw her last. She is not safe yet from the possibility of carcinoma, but there is no sign of it now."

Case 15.—A second case was that of a male, aged forty-nine, recommended by Dr. John Spence. Six weeks before admission to the Electrical Department the patient became aware of a crack on the dorsum of

the tongue, an inch from the tip. This did not tend to heal, and the patient saw his doctor, who cauterized the crack, which had now more the appearance of an ulcer, with zinc chloride. This treatment was repeated on six occasions in a month, in addition to the daily use of glycerine and tannic acid. The condition did not improve. Mr. C. W. Cathcart now saw the patient, and expressed the opinion that it was a case of leucoplakia, and suggested an operation. Treatment by radium was commenced with a weak specimen containing 0·7 milligramme of the pure salt, for half an hour to an hour at a time, at first at the Royal Infirmary, and afterwards by Dr. John Spence. Improvement was rapid, and eight exposures sufficed to bring about a complete cure. The total dose was only 5·6 milligramme hours.

Case 16.—The third case was that of a seaman, aged thirty-seven, recommended by Mr. Wade. This patient had on either side of the tongue two very hard, elevated white patches. As the patient refused operation, vigorous treatment with radium was commenced; but the case could not be followed, for as soon as improvement had begun the patient took a ship and disappeared.

The aluminium container with handle, referred to on p. 19, will be found useful in these cases. It is water-tight, and is easily held by the patient. No screens should be interposed. The dose must depend upon the thickness and duration, etc., of the patch. Case No. 15 was the most satisfactory one, for the

radium brought about a very rapid cure, and it seems to me that in suitable cases this treatment certainly deserves a trial. The applications will be followed by an ulceration, which will cicatrize rapidly.

In **lupus** radium does not seem to be especially indicated. I have seen improvement result from its use in localized cases, but not more than could be obtained by other methods. No screens should be used. Its most useful field in lupus is in cases affecting the cavities which are difficult of access for other methods of treatment. Thus, a tube can easily be placed in the nares, and I have seen good results follow such applications.

In **lupus erythematosus** the remedy is of more potency. In a case affecting the scalp in several discrete areas, to which various remedies had unavailingly been applied (including the zinc ion), a dose of 10 milligramme hours (10 milligrammes for one hour) to each patch produced remarkable improvement, practically amounting to a cure ; but whether this has continued or not I do not know, as I have not seen the patient for several months. The radium should be applied to the borders and a little beyond the borders of the patch. The radium should be directly applied without screens, and full doses should be administered. No success will attend too short or too weak applications. An impetiginous crust will form after the application, and not until this has fallen off will the effect of the treatment be observed. Perfectly healthy, soft, fresh skin was revealed in the case

I have referred to, to the great gratification of the patient.

Dr. Masotti ("Traitement des Dermatoses par le Radium") recommends a preliminary scarification. The scarifications should not be so deep as in lupus vulgaris; they should be followed, after the bleeding has been arrested and the part washed, by the applications of radium.

Cheloid.—Of the treatment of this condition by radium I personally have but little experience. Wickham and Degrais speak highly of it: "Radium exercises on cheloids a most distinct curative action. The results consist, after a proper length of treatment, in the levelling of elevations, the bleaching of erythematous cheloids, the removal of the pain in the case of painful cheloids, and the restoration of suppleness to the tissues. The most important point in the treatment, and one which the practitioner must never lose sight of, is the necessity of influencing the cheloid to its very base, and of attacking the peripheral roots, which often extend beyond the visible limits. Either the specific or the destructive action of radium can be used. The docility of the tissues of a cheloid, when brought in contact with radium, depends upon its specific action, which causes them to melt away without becoming the seat of the slightest irritation. The cheloids which are most amenable to radium are those of recent formation and in process of evolution, and those affecting young children" ("Radium-thérapie, p. 174).

By employing moderate doses the specific action of radium might be tried for cheloids of the latter class, and, by employing larger doses, the destructive action in old sclerotic cheloids.

In the case of a suppurating tuberculous gland which had been operated on, and in which a discharging sinus had been left, and a cicatricial elevation and ridge, I tried the effect of radium, but, as the result of every dose was to cause the sinus to close, I had to discontinue its employment.

Masotti recommends the use of powerful apparatus and of destructive doses in cheloid and in cicatricial ridges, particularly in the latter. He also suggests the combination of scarification and of radium applications, as it shortens the duration of the treatment. The duration will depend upon the age of the cheloid and of the patient, and the density and breadth of the cheloid. Screens should not be used.

CHAPTER X

DISEASES OF THE NERVOUS SYSTEM—TUBERCULAR GLANDS—PRURITUS—EYE DISEASES—UTERINE CANCER—RHEUMATIC CONDITIONS—COMPARISON BETWEEN X RAYS AND RADIUM RAYS

Diseases of the Nervous System.—Radium has been used for its analgesic action in neuralgia, sciatica, and the lightning pains of locomotor ataxy, and also for certain affections of the spinal cord associated with cellular overgrowth. In the *Progrès Médical* of December 18, 1909, Mme. Fabre and Dr. Paul Touchard, of the Salpêtrière Hospital, report a series of five cases of syringomyelia treated by exposure to radium, with surprising effect.

A piece of flat metal was employed, 6 centimetres square, containing 1·5 centigrammes of pure radium bromide, and a nickel screen 0·33 millimetre thick, sufficient to allow only hard beta and gamma rays to get through. The applications were made daily to the vertebral column, at various levels, alternately to the right and to the left of the spinous processes. The duration of the exposure was at first restricted to ten

minutes, but evidence of the innocuousness of the applications led to their being extended to as long as an hour and a half. The record is certainly an encouraging one. All five cases improved, three of them to a remarkable degree. All showed increased mobility of the limbs, with diminution of stiffness. One patient's hands had been quite helpless, in a *main en griffe* position, but after radium treatment she was able to flex, extend, and separate the fingers. A second was able to resume his work as a draughtsman after six months' disuse of pencil and compasses. Another remarkable fact was the disappearance, in one case, of the trophic disturbances characteristic of Morvan's disease. The effect on the muscular atrophy was less obvious. Improvement set in very rapidly. From the theoretical standpoint, there is reason to suppose that the action of radium on the syringomyelic cord is analogous to its accepted action on neoplastic tissue. By some mechanism unknown to us, the rays check the proliferating tendency of the cellular elements of new growths, and, on this analogy, it is perhaps only in developing cases of syringomyelia that they are likely to be of service (*Lancet*, January 22, 1910). It has been shown by Beaujard, L'Hermitte, Raymond, and others, that the X rays have a favourable influence on syringomyelia, and it is therefore to be expected that the gamma rays of radium would have a somewhat analogous effect, and more potent, in consequence of the ease with which they can penetrate the bodies of the vertebræ.

Tubercular Glands, Pruritus, X-ray Dermatitis. —As X rays are of acknowledged service in enlarged glands, so are radium rays. I will refer only to some remarks made by Sir Malcolm Morris in the discussion on Wickham's paper on July 20, 1909, and reported in the *British Medical Journal* of August 21, 1909. "Recently he had a case in which the tuberculous glands had been removed on three different occasions, and in order to avoid another surgical investigation, which seemed likely to be equally unavailing, he thought he would try the effect of radium. There were three tuberculous glands. There could be no question as to the accuracy of the diagnosis, for there were the previous operations to go upon and the microscopical proof. He used a filter of lead 2 millimetres in thickness, and gave long exposures, two hours a day for six days, on one gland. At the end of three weeks there was not a trace of the gland left; moreover, the skin was untouched, and there was no sign of a burn. The other glands were treated in the same way, with the same result."

Drs. Wickham and Degrais, Deane Butcher, and others, have reported good results in rebellious pruriginous conditions and in simple pruritus. Dr. Mackenzie Davidson treated some patches of X-ray dermatitis on his own hands with a 29-milligramme tube of radium for ten minutes, with success. After the reaction had subsided the part was soft and pliable, and not cicatricial, as it would have been under the cautery. He had also obtained remarkable improve-

ment by treating in the same way the extensive lesions on the hands of an X-ray operator.

Dr. Deane Butcher has found that the application of radium has a soothing effect upon X-ray burns, something like that of cocaine. We know also, on his excellent authority, that radium is unapproachable in the treatment of pruritus.

Diseases of the Eye.—The advances that have been made in the treatment of diseases of the eye by radium we owe to Dr. Mackenzie Davidson, who in his introductory address, as President of the section of Radiology, at the meeting of the British Medical Association in July, 1910, made the following remarks: " But if radium has not so far fulfilled all the hopes that were entertained of it, it has, at any rate, accomplished something, and it is encouraging to turn for a moment to a new field of experiment in which it has yielded good and definite results—namely, certain diseases of the eye. Here, again, the diseases in which it is potent are 'superficial.' So far as we have tried it in deep-seated diseases, the results are negative. On the other hand, in some external diseases of the eyes and eyelids, its action is very remarkable, and I feel sure that radium will take a high place in ophthalmic therapeutics. By way of example, I may instance five cases of spring catarrh which I have cured by radium. The first of these was cured four years ago, and there has been no recurrence. Some of these cases were extremely

severe, and one of them, of over six years' standing had undergone a great variety of treatment, both operative and otherwise, without any permanent benefit. And besides these, in cases of episcleritis, hypopyon ulcers (corneal ulcers generally), incipient keratitis, and even in bad cases of pterygium, extraordinarily good results have been obtained."

Spring Catarrh—Case 17.—A boy aged six, a patient of Dr. George Mackay's, was recommended to the Electrical Department of the Royal Infirmary, Edinburgh, on March 4, 1910, suffering from spring catarrh. Both upper lids were covered on their internal surface with the typical granulations and irregular, pavement-like blocks. The lids were much swollen. The disease had lasted some months (Plate XII.). It was decided, after consultation with Dr. Mackay, to treat the right upper lid only. At first an ebonite capsule with a mica window, containing 10 milligrammes of pure bromide of radium, was held as close, without touching, as possible to the everted lid for ten minutes a day. After a short time, as the boy attended as an out-patient, and could only come in once a week, more prolonged exposures by a relay of assistants were given. The radium was also enclosed in an aluminium box to avoid the risk of wetting it. Three or four weeks elapsed before any improvement could be observed, and then it was very slow, but steady. Owing to the demand for radium by more serious cases, a weak preparation containing 1 milligramme of the pure salt was substituted for

PLATE XII.

FIG. 27.—SPRING CATARRH, TREATED AND UNTREATED.

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the strong specimen. The boy was made to lie down, and the glass tube containing the salt was fastened by plaster directly against the everted lid. On May 10, 1910, the right eye showed a great improvement, only one nodule being left; but the left or untreated eye was as bad as ever. At the end of June, as the right eye was practically well (Fig. 27), treatment of the left eye was begun. The right eye had received a total dose of 32·5 milligramme hours.

This case confirms Dr. Mackenzie Davidson's results, and it would appear that in radium properly applied we possess a powerful remedy for spring catarrh.

Radium in Gynæcology.—Work has been done in the direction of treating metritis, salpingo-ovaritis, etc., and malignant disease of the uterus, by Wickham and Degrais, Cheron, Tuffier, and others. Mme. Fabre collected a series of cases under Broca, Cuneo, Oudin, and Cheron, where radium-therapy was employed, in which she claims that beneficial results were obtained. Professor Tuffier submitted some of his patients suffering from uterine cancer to radium treatment in the Beaujon Hospital. A glass tube containing 9 centigrammes of pure radium bromide, enclosed in a silver tube 1 millimetre thick, was placed inside a rubber drain-pipe and introduced into the cancerous uterus. It was applied every sixth day, and left *in situ* for twelve hours at a time. The patient had been operated on eight months previously for cancer of the uterus; she now returned with a

recurrence in the vaginal cicatrix and the foot of the broad ligament. As a result of the treatment five-sixths of the pathological infiltration disappeared, but an induration persisted. In order to judge of the results obtained, sections were cut out of the tissue treated by radium, and from these Professor Tuffier draws the following conclusions, which are subject to modification:

1. The radiations penetrated to at least a depth of 2 centimetres.

2. The action of the radiations on the cancerous tissue was produced slowly; the absence of any morphological tissue modification for six or more days does not in any way imply that no action will follow later.

3. The action of the radiations was on the cancer cells and on the connective-tissue framework, but not equally; for the connective tissue was the less rapidly affected, the action being first and especially an elective one on the cancer cell.

Professor Tuffier compared these results with those produced by the X rays, and found that the latter were powerless in dealing with subcutaneous cancers; but in ulcerating, bleeding, and granulating tumours they exercised an incontestable hæmostatic action, causing cicatrization and producing an anæsthetic effect, but the healing was superficial and left the deep cancer intact. Microscopic examination of cancer treated by X rays showed that their action was specific on the cancer cell; there was an elective necrosis of

the neoplastic elements. But this action was very limited as to depth, and that often in spite of apparent cure. Active neoplastic elements were found at a depth of less than 2 millimetres from the surface treated; atrophied cells were found in the most superficial portions, but active cancer cells with karyokinesis were found in the subjacent layer (*British Medical Journal*, February 13, 1909).

Rheumatic Conditions — Use of Radio-active Earths. — Reference has already been made (p. 26) to the production and use of the emanation. It can also be administered by the employment of radio-active earths. One of the best known of these is obtained in the process of uranium extraction; it contains certain oxides of iron, aluminium, uranium, and manganese, and traces of actinium, radium, and polonium. Of the latter, actinium is the most important. Pure actinium is estimated by some physicists * to be ten times as radio-active as radium; the quantity present in the earth suffices to confer upon it a radio-activity of 0·15 as compared to 2,000,000 in the case of radium.

The following is a table of comparative radio-activities (Claude).

Actinium	...	(about) 20,000,000
Radium	...	,, 2,000,000
Uranium	...	... 1
Earth	...	... 0·15

* Pure actinium has not been isolated, but it is believed that it would show an activity comparable with that of radium (Rutherford).

One centigramme of the earth spread over one square centimetre yields a radiation about one-seventh the strength of that of uranium. The earth is an extremely weak radio-active preparation, which yields alpha, beta, and gamma rays, and an emanation. It is, however, relatively to radium, very cheap, a kilogramme costing thirteen shillings.

The earth has been employed for some time by Dr. Claude and others in the hospitals of Paris in the treatment of arthritis deformans, subacute and chronic rheumatism, and gonorrhœal rheumatism, also for neuralgia and certain cutaneous (pruritus) and gynæcological affections.

The affected joint having been cleansed, the moistened earth is spread in the form of a compress around it, and maintained in position by a piece of oil-silk and a bandage. It must not be allowed to become dry. No emanation would be given off if it became dry. The plaster can be left on all night, and applied on alternate nights for ten days.

It should always be remoistened and made quite plastic and soft before application. It does not lose its strength. In some cases it may be advisable to sterilize it by heat (open sores, introduction into the cavities of the body); this will not affect its activity.

Dr. Guyenot (*Lancet*, October 15, 1910) prepares a radio-active earth or mud by mixing powdered pitchblende with twice its volume of hot water. This is applied direct to the part to be treated, and can be left on several hours under a piece of waterproof.

This mud exercises a sedative effect, and is believed to promote the absorption of exudations. It does not irritate the skin, its radio-activity is permanent; but when it has been used, it must be allowed to dry for a fortnight before it is used again.

Another method of employing the earth is to make use of baths. Two hundred and fifty grammes of the earth are mixed with the warm water of the bath; more may be used if desired, but this is the usual strength. The patient can remain in the bath for half an hour, and have a series of a dozen in a fortnight or longer.

Good results are claimed to have been obtained by Claude and Teulière (*Brit. Med. Journ.*, March 12, 1910) in arthralgia and subacute forms of arthritis. The pain, redness, and swelling, usually disappear with great rapidity, but affections of the lower limb appear to be more rebellious than those of the upper limb. The best results appear to have been obtained in subacute gonorrhœal rheumatism.

Mud baths have been for a long time in vogue at certain health resorts; it is possible that the beneficial results may have depended upon the presence of traces of radio-active substances. The same may be said of certain mineral waters.

General Comparison between X-Ray and Radium Treatment.—Whether there is any specific therapeutic difference between X-ray and radium radiations is a question not yet settled. I have observed that certain rodent ulcers which were refractory to

X rays yielded rapidly to radium, but apart from this both methods have relative advantages and disadvantages.

The gamma rays of radium are far more penetrating than X rays; Tuffier found their effect manifest on the tissues at a depth ten times as great as that of X rays. Hence they are to be preferred for deep-seated affections (syringomyelia, subcutaneous cancers, tuberculous glands, etc.). Radium rays are perfectly "constant" in quantity and quality as opposed to X rays, of which one may say, "Varium et mutabile semper"; hence a dose of radium rays can be measured with a precision that is wanting in the case of the X rays. Radium can be placed in natural cavities or buried in tumours, and left for an indefinite period, giving off its radiation all the time. The quality of the reparation tissue left after radium treatment leaves nothing to be desired, and is superior to that following X-ray treatment. So perfect is the scar after treatment with radium that it is sometimes difficult to find the site of the previous lesion. Radium dermatitis is not so painful or intractable as X-ray dermatitis. Radium is readily portable from patient to patient, and can be left to be applied by others after instruction.

Against these advantages is to be set the very great disadvantage of its extremely high price. To this must be added the risk of loss by breakage or accident. The chief advantage of the X rays over radium is the large area to which the former can be applied.

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